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Rivard et al.

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(54) **IMAGE SENSOR APPARATUS AND METHOD FOR OBTAINING MULTIPLE EXPOSURES WITH ZERO INTERFRAME TIME**

(71) Applicant: **Duelight LLC**, Sunnyvale, CA (US)

(72) Inventors: **William Rivard**, Menlo Park, CA (US); **Adam Feder**, Mountain View, CA (US); **Brian Kindle**, Sunnyvale, CA (US)

(73) Assignee: **Duelight LLC**, Sunnyvale, CA (US)

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(51) **Int. Cl.**

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H04N 5/228	(2006.01)
H04N 5/235	(2006.01)
H04N 5/232	(2006.01)
H04N 5/243	(2006.01)

(52) **U.S. Cl.**
CPC ***H04N 5/2355*** (2013.01); ***H04N 5/2352*** (2013.01); ***H04N 5/2353*** (2013.01); ***H04N 5/243*** (2013.01)

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CPC H04N 5/2351; H04N 5/2354; H04N 5/23232; H04N 5/2355; H04N 5/23229; H04N 5/23238; H04N 3/1593; H04N 5/2356
USPC 348/211.1–211.99, 218.1, 222.1
See application file for complete search history.

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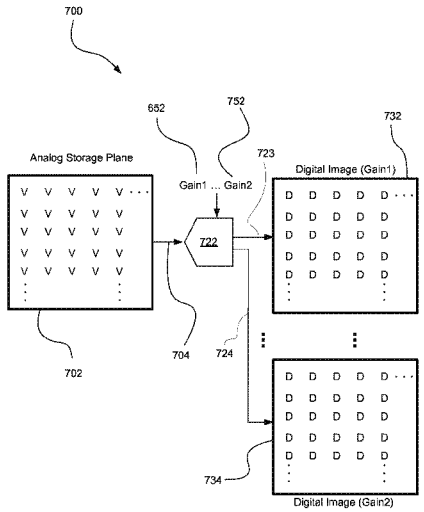
Primary Examiner — Chia-Wei A Chen
(74) *Attorney, Agent, or Firm* — Zilka-Kotab, PC

(57) **ABSTRACT**

A system, method, and computer program product are provided for obtaining multiple exposures with zero interframe time. In use, a first an analog signal associated with an image is received from at least one pixel of an image sensor. Next, a first amplified analog signal associated with the image is generated by amplifying the analog signal utilizing a first gain. Further, a second amplified analog signal associated with the image is generated by amplifying the analog signal utilizing a second gain. Finally, the first amplified analog signal and the second amplified analog signal are transmitted.

15 Claims, 17 Drawing Sheets



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2015/0092852	A1*	4/2015	Demos	375/240.15
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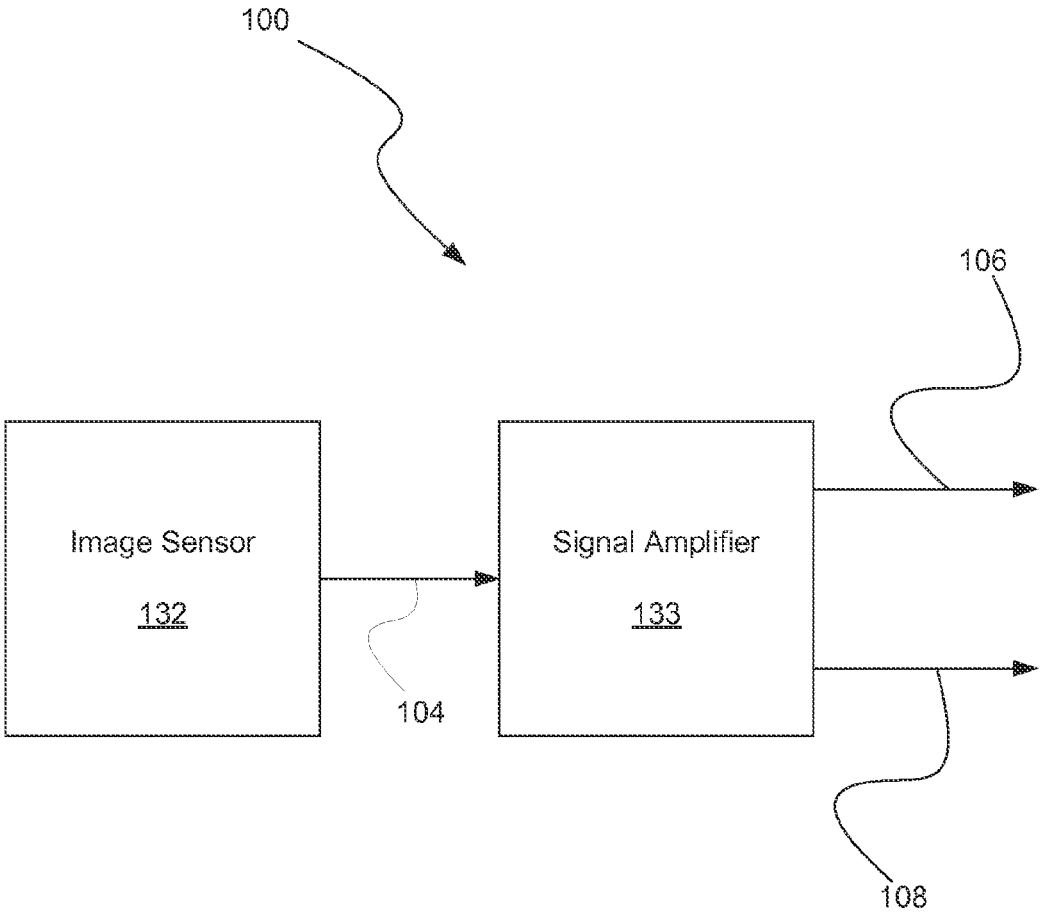


Figure 1

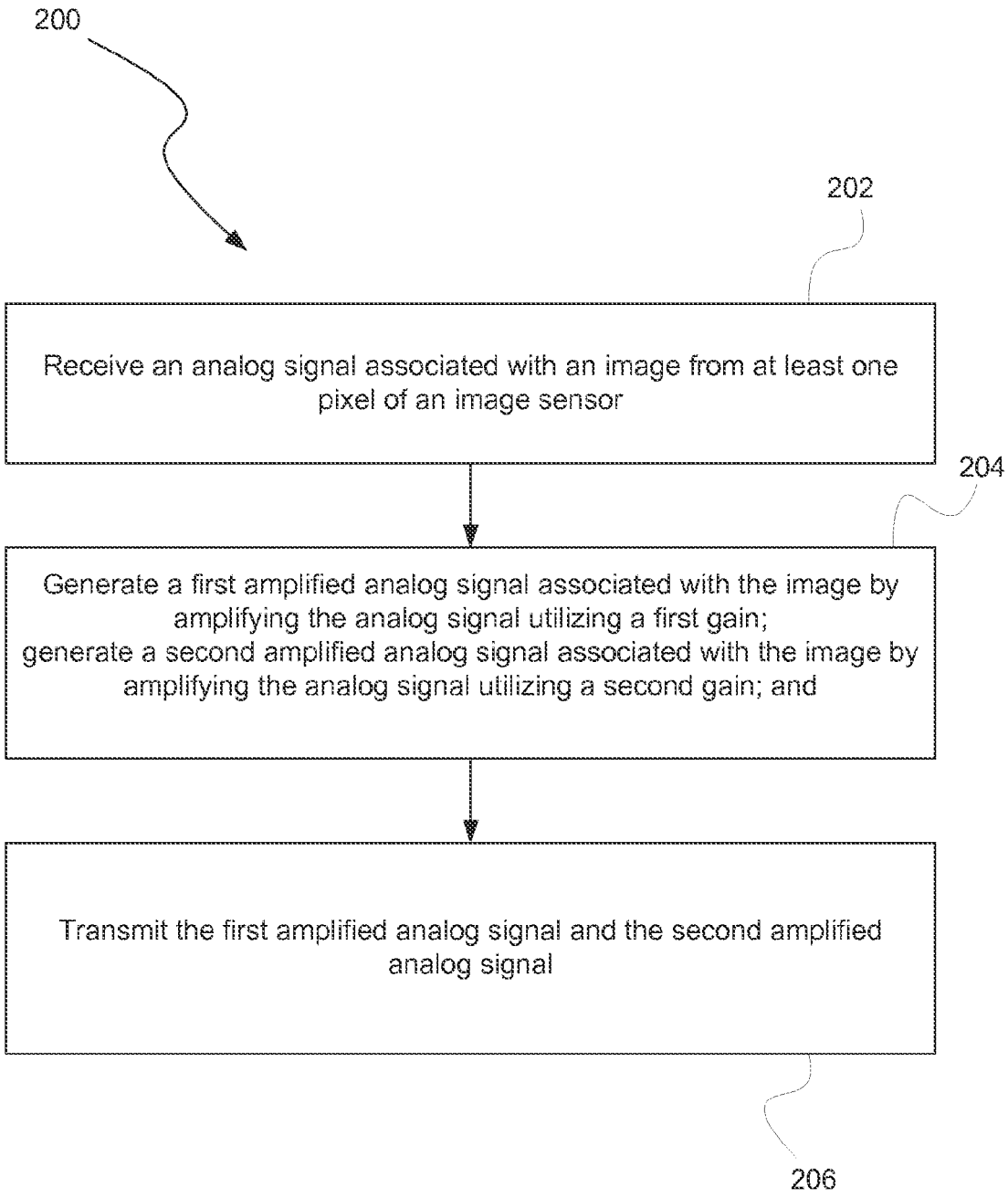

200
202
Receive an analog signal associated with an image from at least one pixel of an image sensor
204
Generate a first amplified analog signal associated with the image by amplifying the analog signal utilizing a first gain;
generate a second amplified analog signal associated with the image by amplifying the analog signal utilizing a second gain; and
Transmit the first amplified analog signal and the second amplified analog signal
206

Figure 2

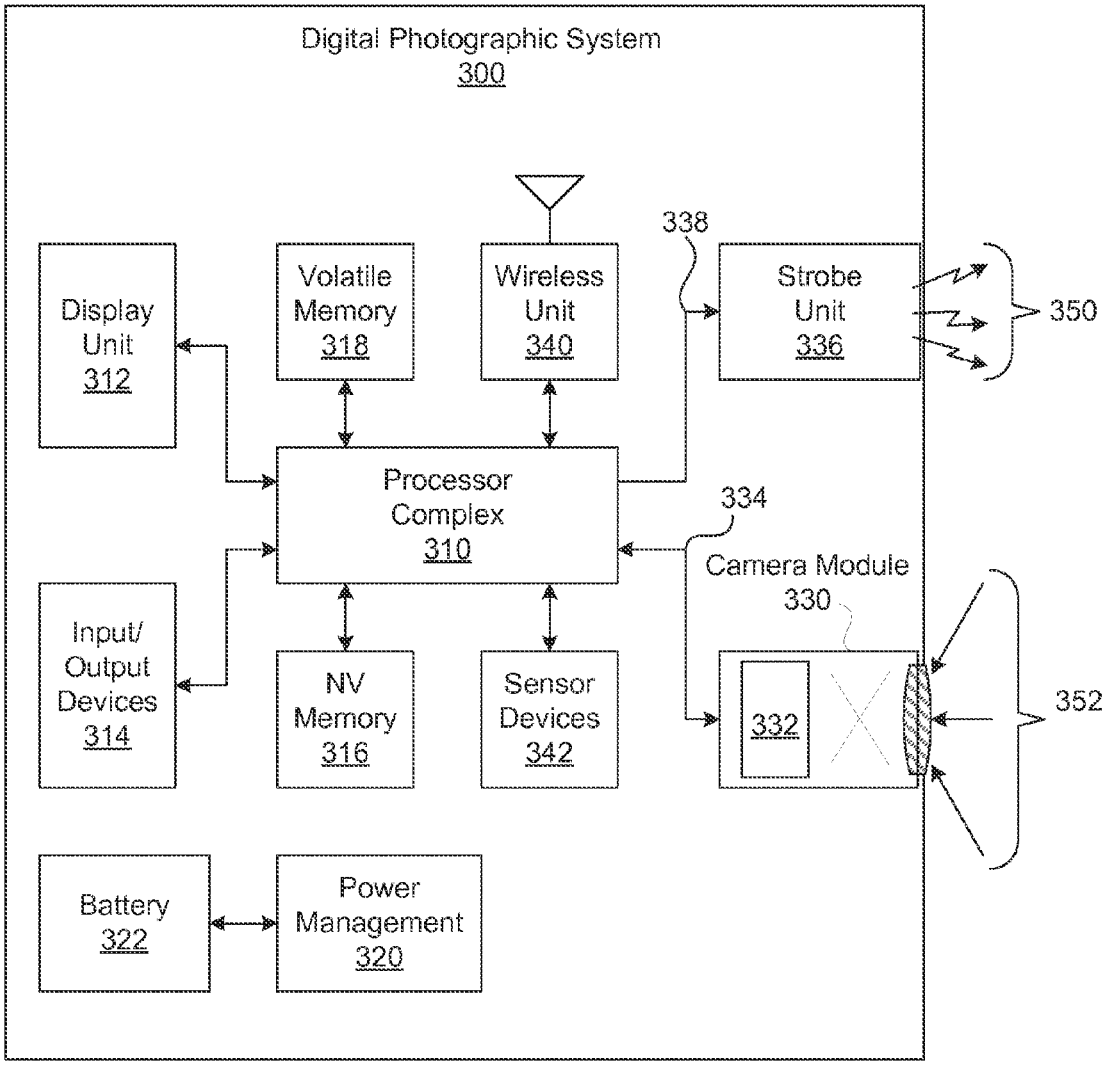

Digital Photographic System
300
Display Unit 312
Volatile Memory 318
Wireless Unit 340
338
Strobe Unit 336
350
Processor Complex 310
334
Camera Module 330
Input/ Output Devices 314
NV Memory 316
Sensor Devices 342
332
352
Battery 322
Power Management 320

Figure 3A

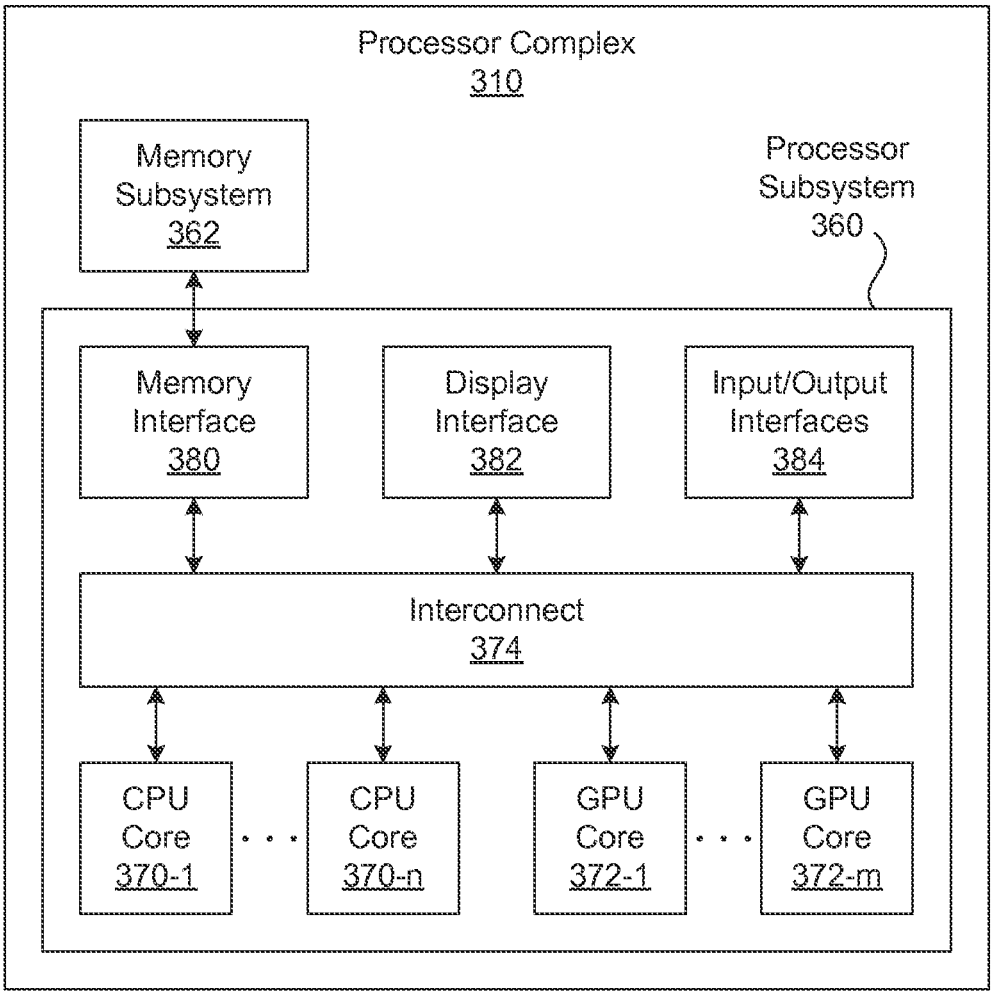

Processor Complex
310
Memory Subsystem
362
Processor Subsystem
360
Memory Interface
380
Display Interface
382
Input/Output Interfaces
384
Interconnect
374
CPU Core
370-1
CPU Core
370-n
GPU Core
372-1
GPU Core
372-m

Figure 3B

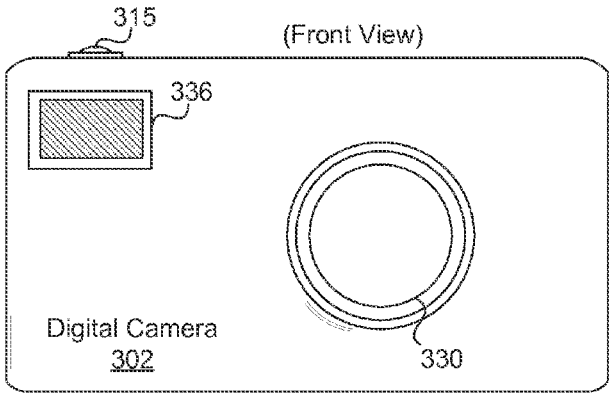


Figure 3C

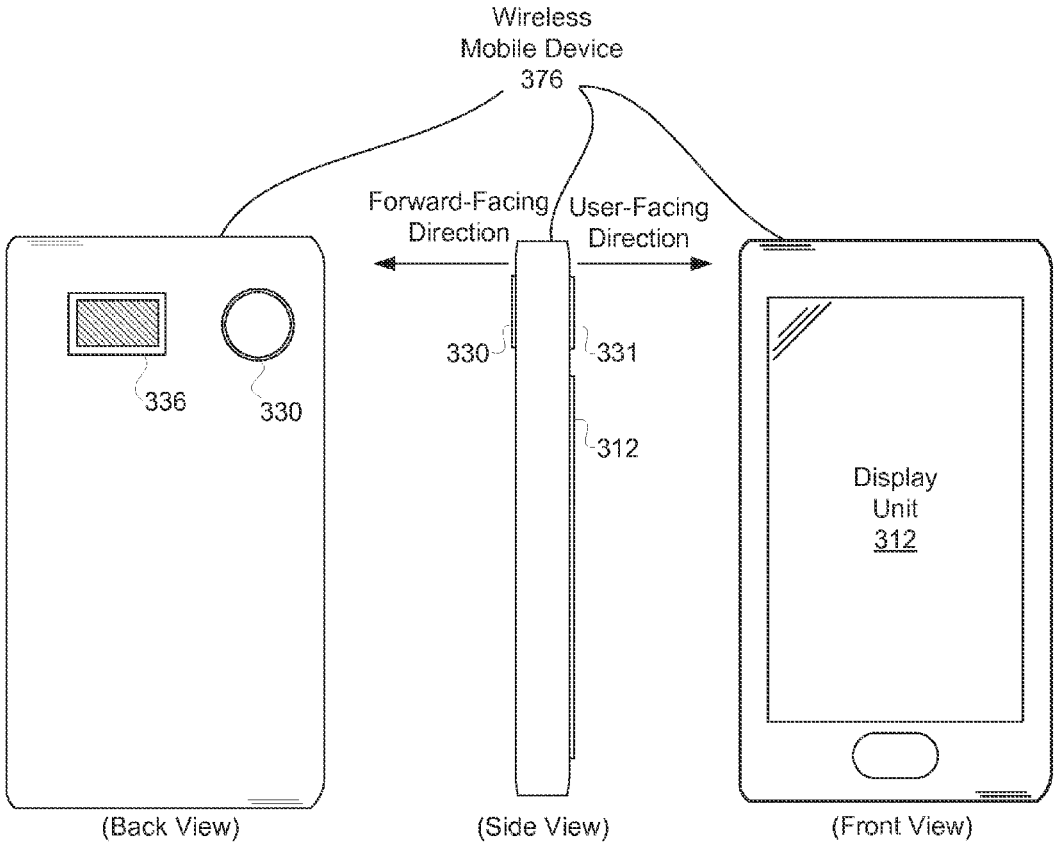


Figure 3D

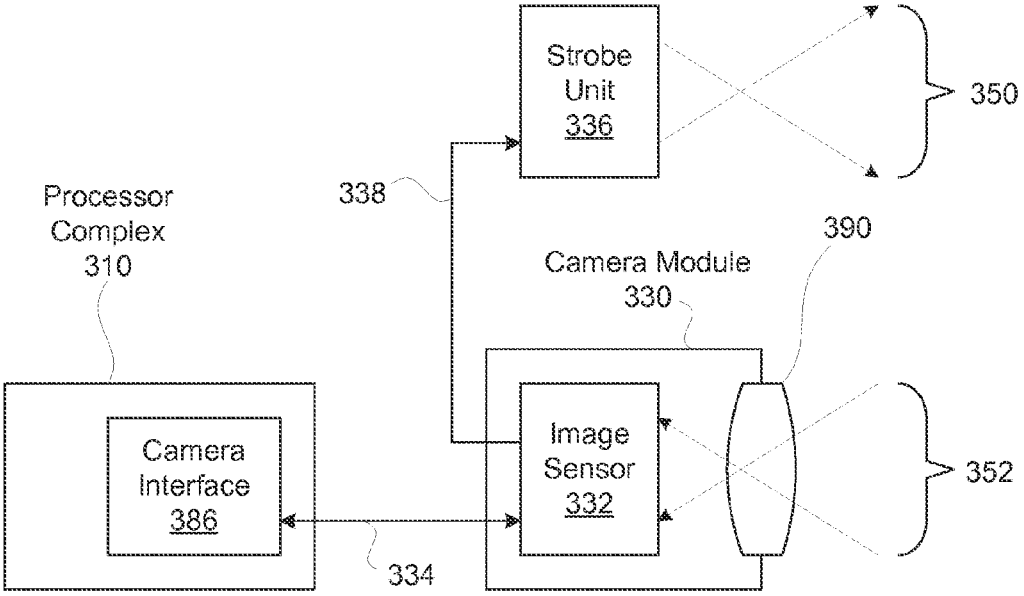
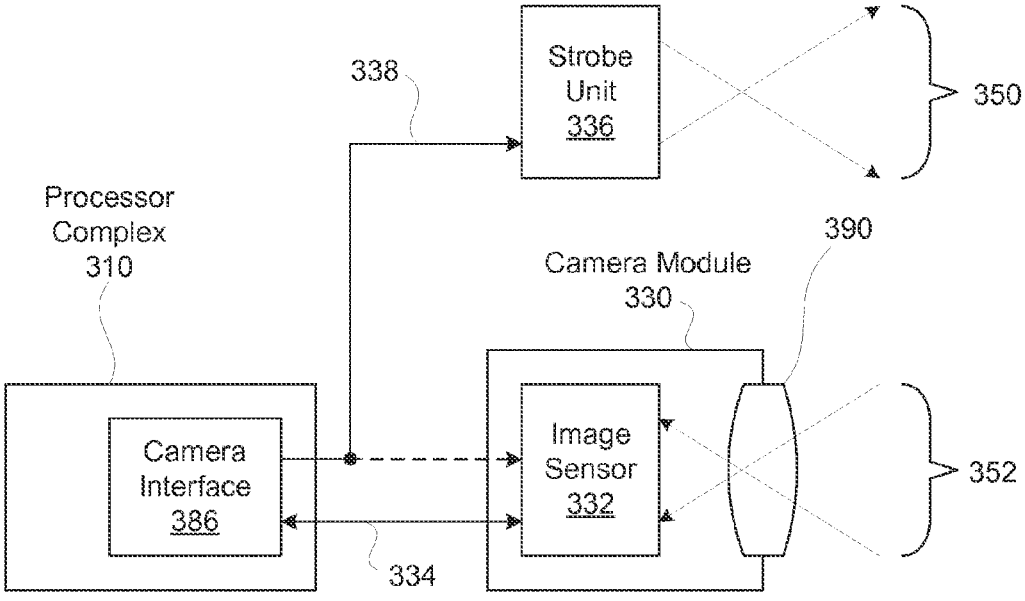


Figure 3E



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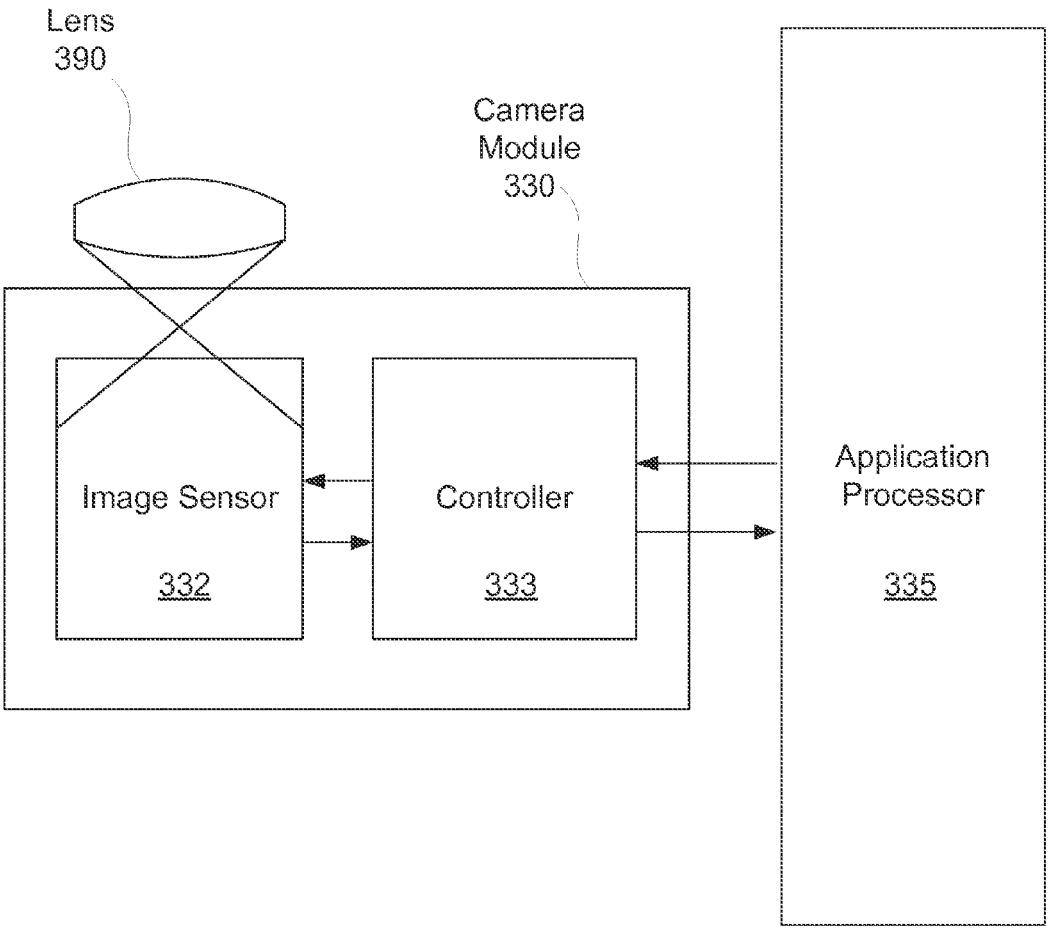
Lens
390
Camera
Module
330
Image Sensor
332
Controller
333
Application
Processor
335

Figure 3G

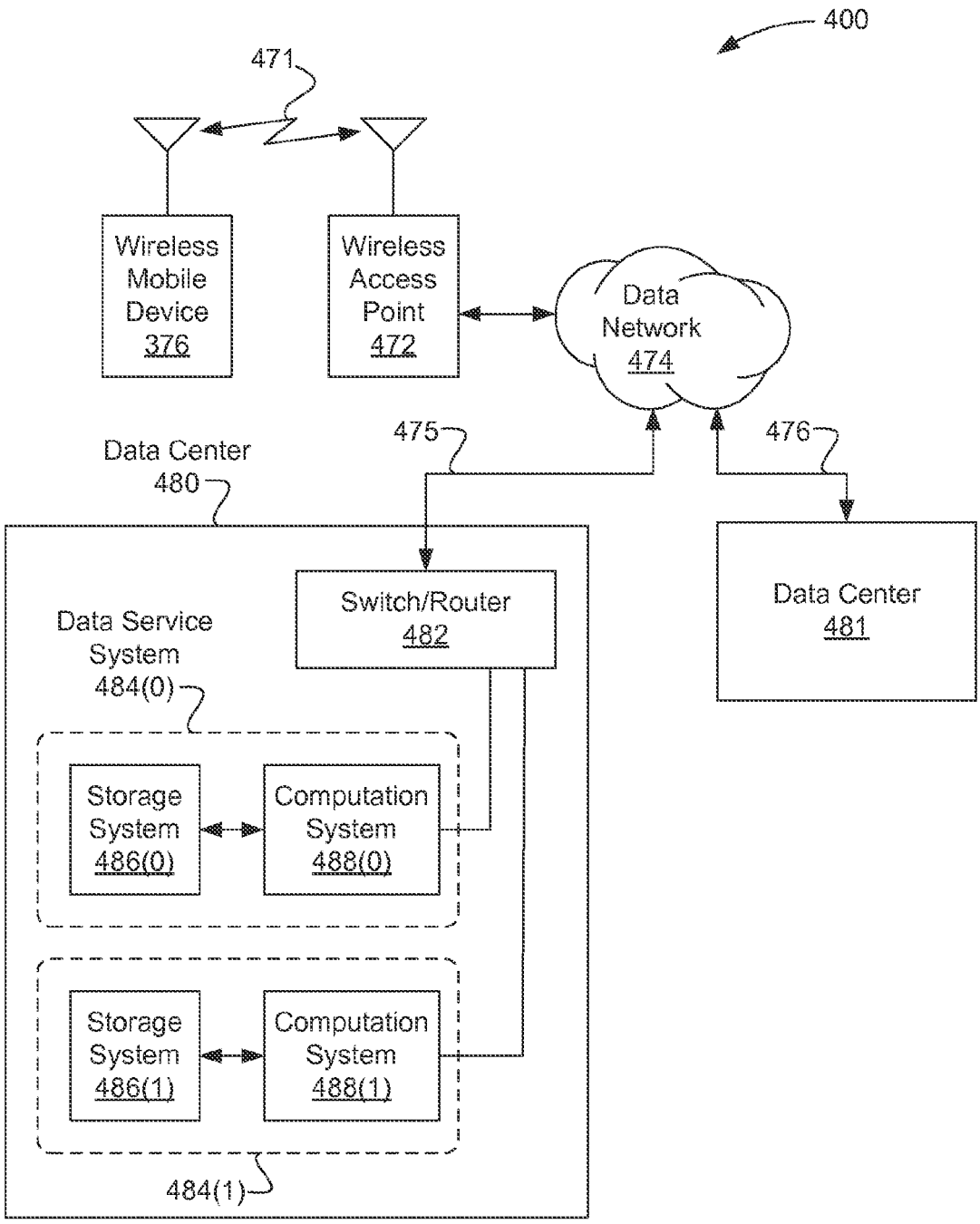
400
471
Wireless Mobile Device 376
Wireless Access Point 472
Data Network 474
475
476
Data Center 480
Switch/Router 482
Data Center 481
Data Service System 484(0)
Storage System 486(0)
Computation System 488(0)
Storage System 486(1)
Computation System 488(1)
484(1)

Figure 4

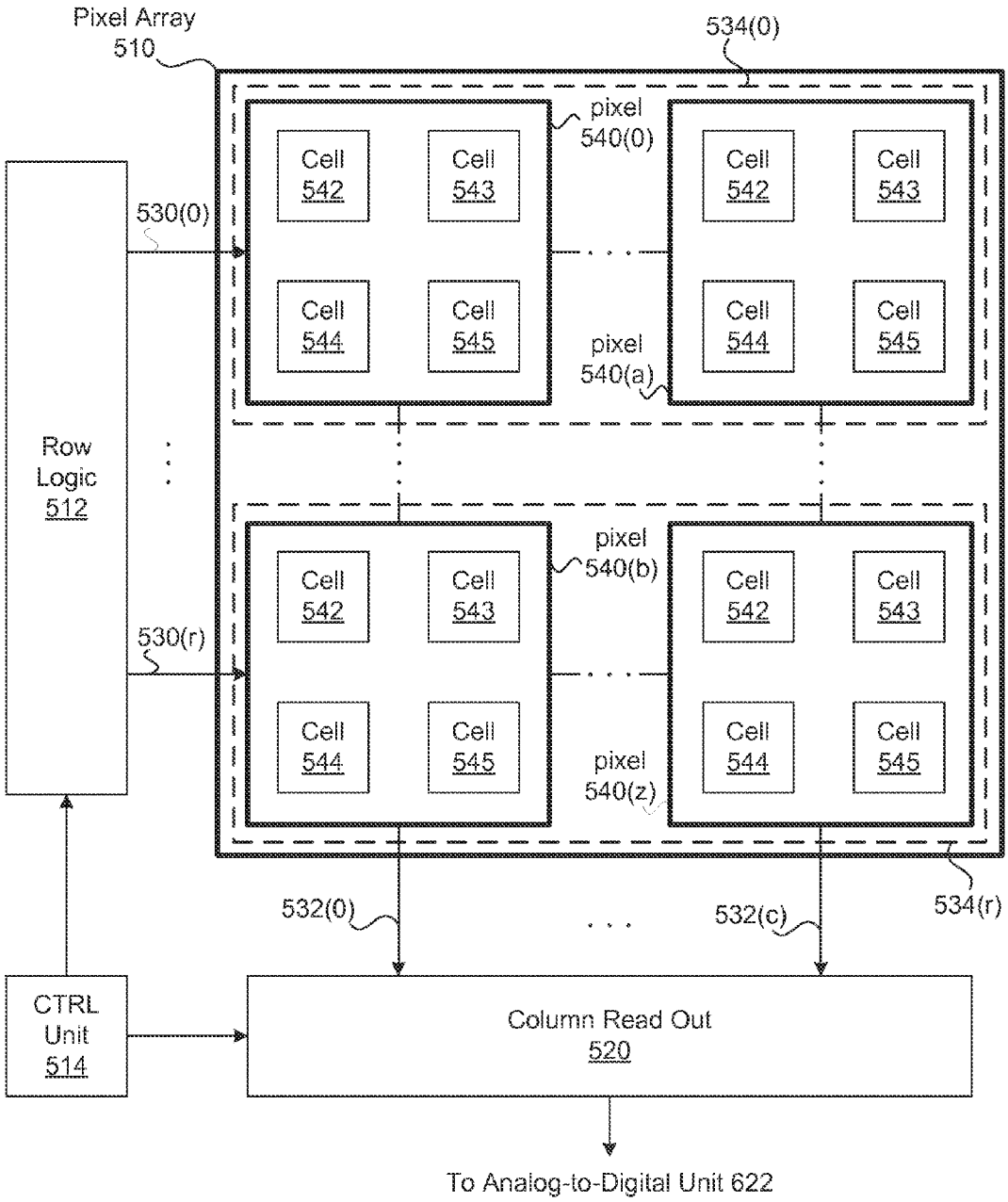
Pixel Array
510
534(0)
pixel
540(0)
Cell
542
Cell
543
Cell
544
Cell
545
530(0)
Row
Logic
512
pixel
540(a)
pixel
540(b)
530(r)
pixel
540(z)
532(0)
532(c)
534(r)
CTRL
Unit
514
Column Read Out
520
To Analog-to-Digital Unit 622

Figure 5A

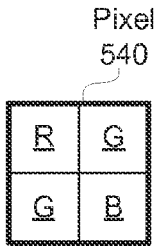

Figure 5B

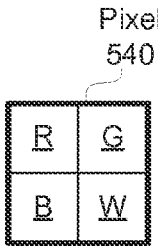

Figure 5C

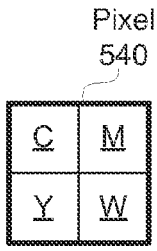

Figure 5D

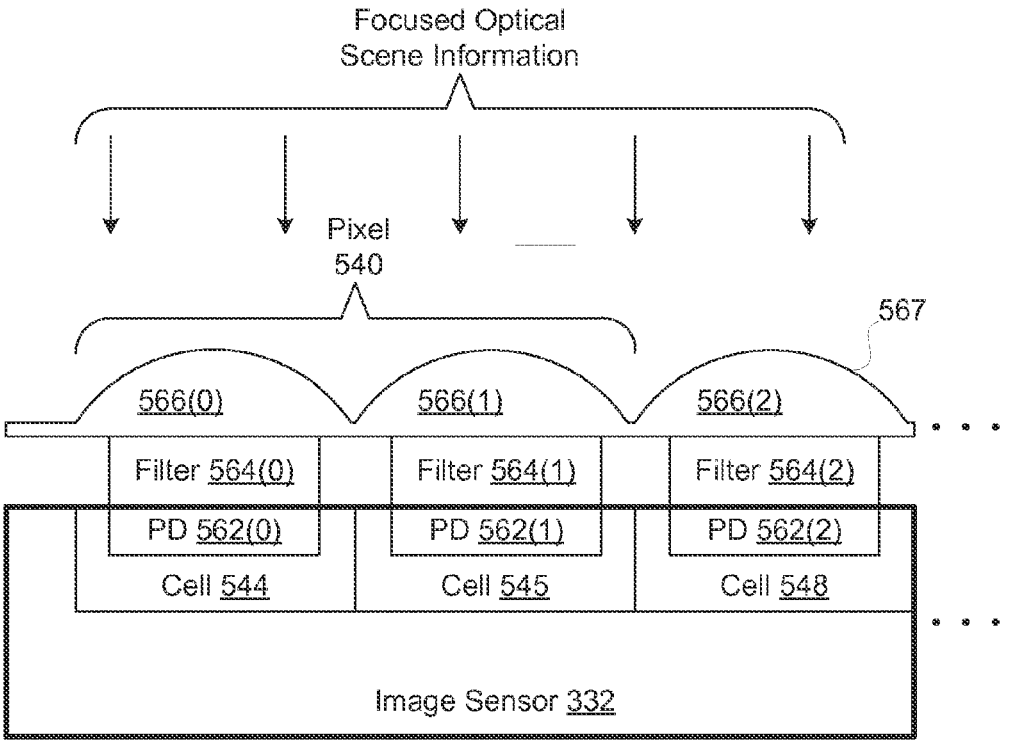

Figure 5E

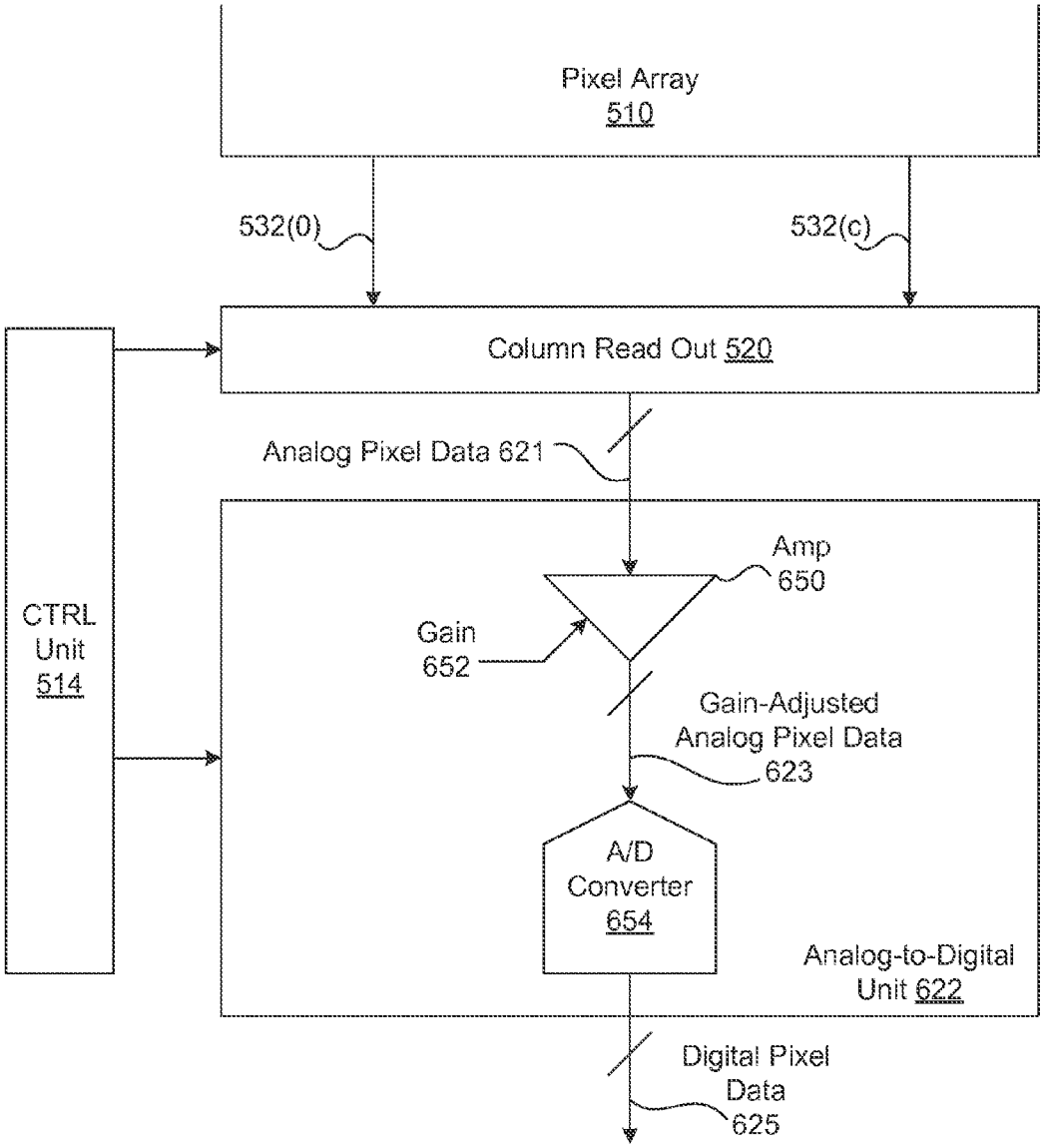
Pixel Array
510
532(0)
532(c)
Column Read Out 520
Analog Pixel Data 621
CTRL
Unit
514
Amp
650
Gain
652
Gain-Adjusted
Analog Pixel Data
623
A/D
Converter
654
Analog-to-Digital
Unit 622
Digital Pixel
Data
625

Figure 6

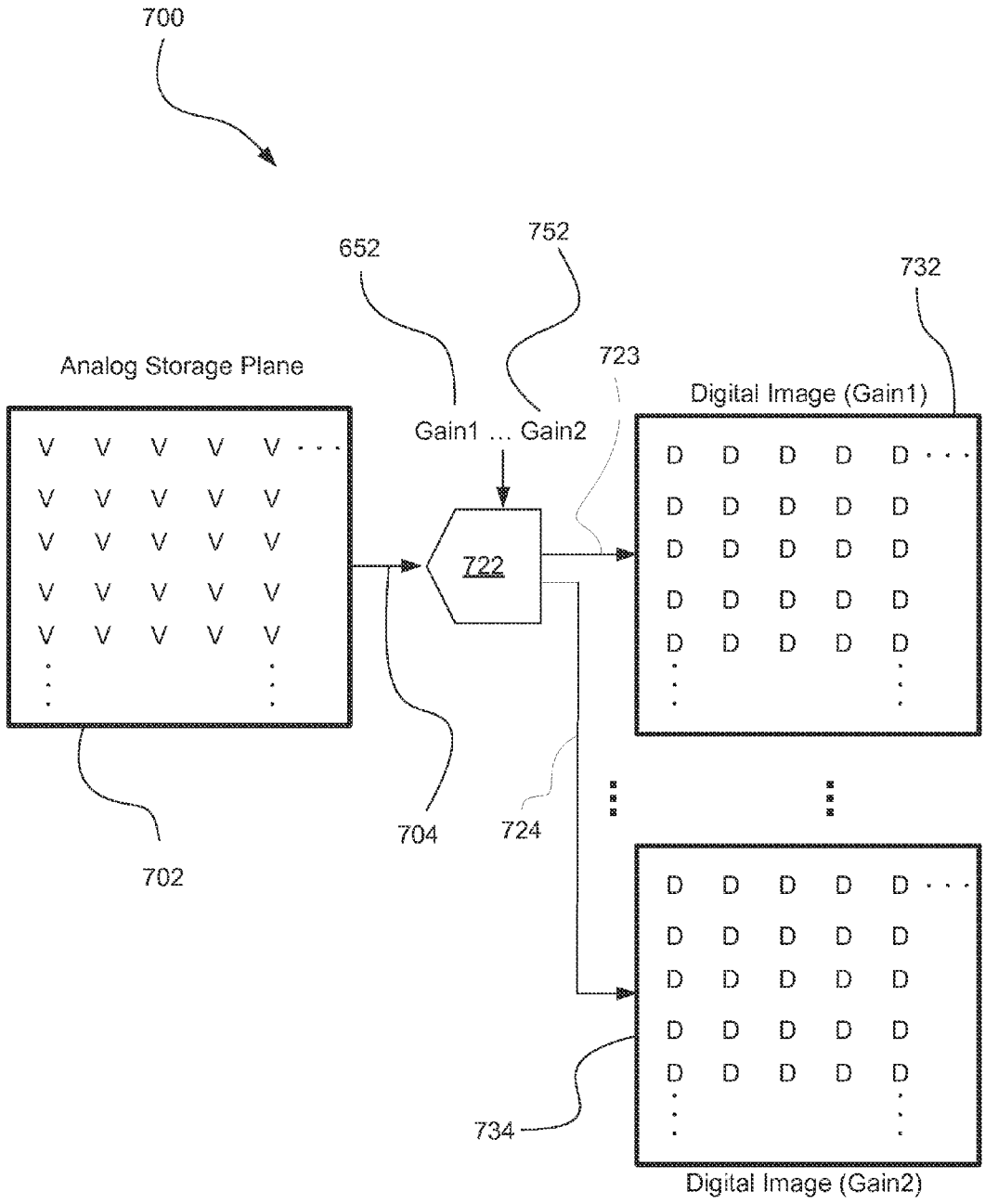
700
652
752
732
Analog Storage Plane
723
Digital Image (Gain1)
Gain1 ... Gain2
722
704
724
702
734
Digital Image (Gain2)

Figure 7

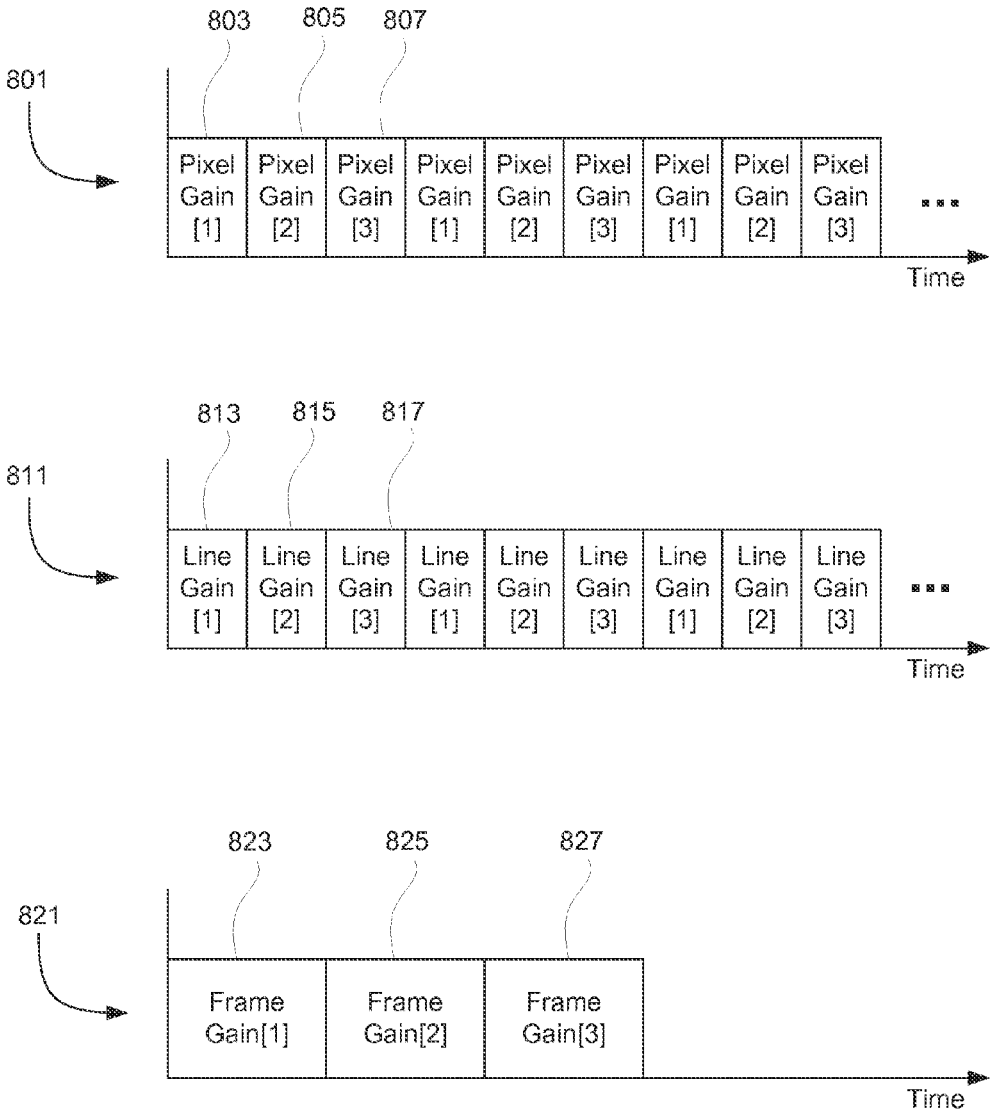
801
803
805
807
Pixel Gain [1]
Pixel Gain [2]
Pixel Gain [3]
Pixel Gain [1]
Pixel Gain [2]
Pixel Gain [3]
Pixel Gain [1]
Pixel Gain [2]
Pixel Gain [3]
Time
811
813
815
817
Line Gain [1]
Line Gain [2]
Line Gain [3]
Line Gain [1]
Line Gain [2]
Line Gain [3]
Line Gain [1]
Line Gain [2]
Line Gain [3]
Time
821
823
825
827
Frame Gain[1]
Frame Gain[2]
Frame Gain[3]
Time

Figure 8

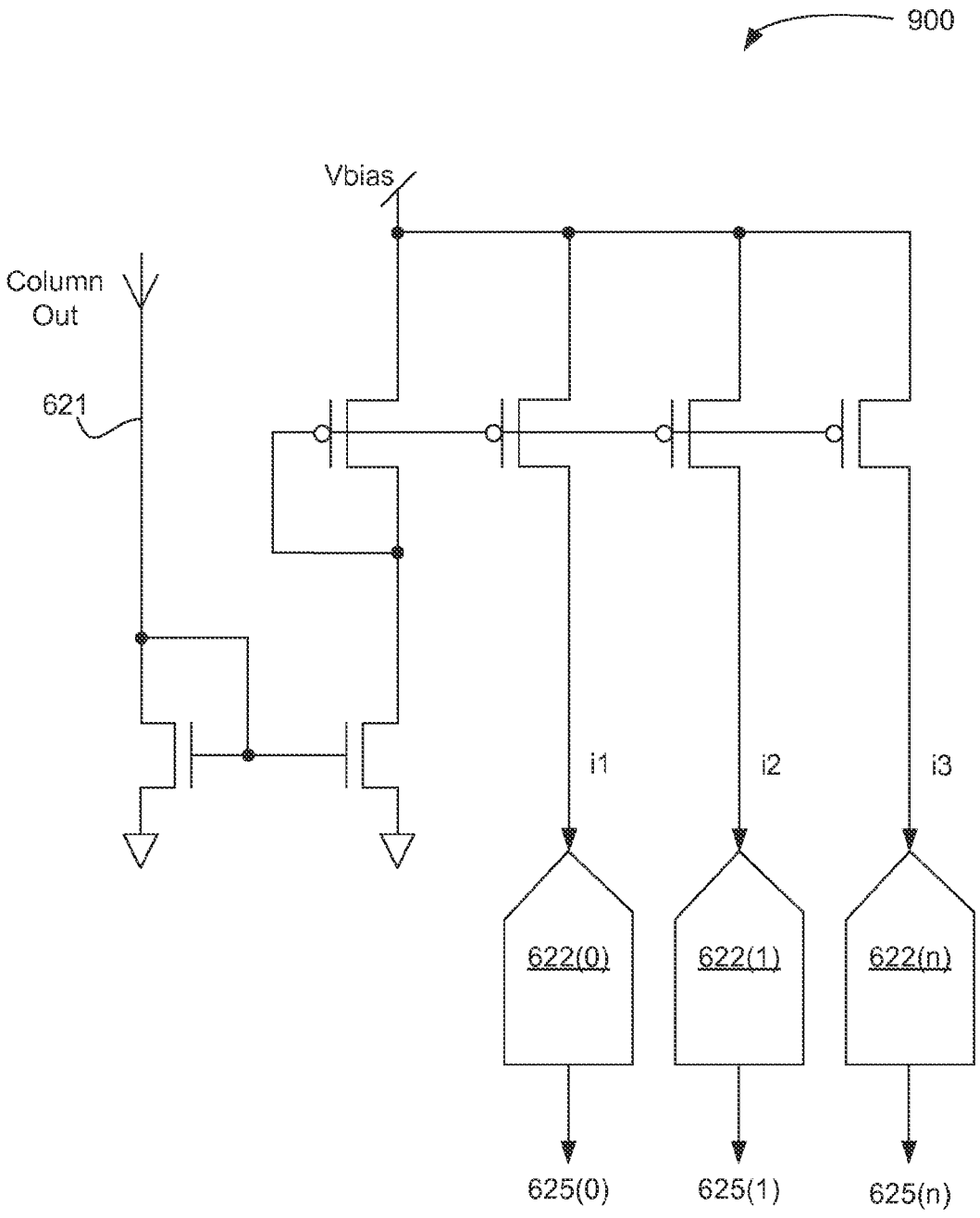
900
Vbias
Column Out
621
i1
i2
i3
622(0)
622(1)
622(n)
625(0)
625(1)
625(n)

Figure 9

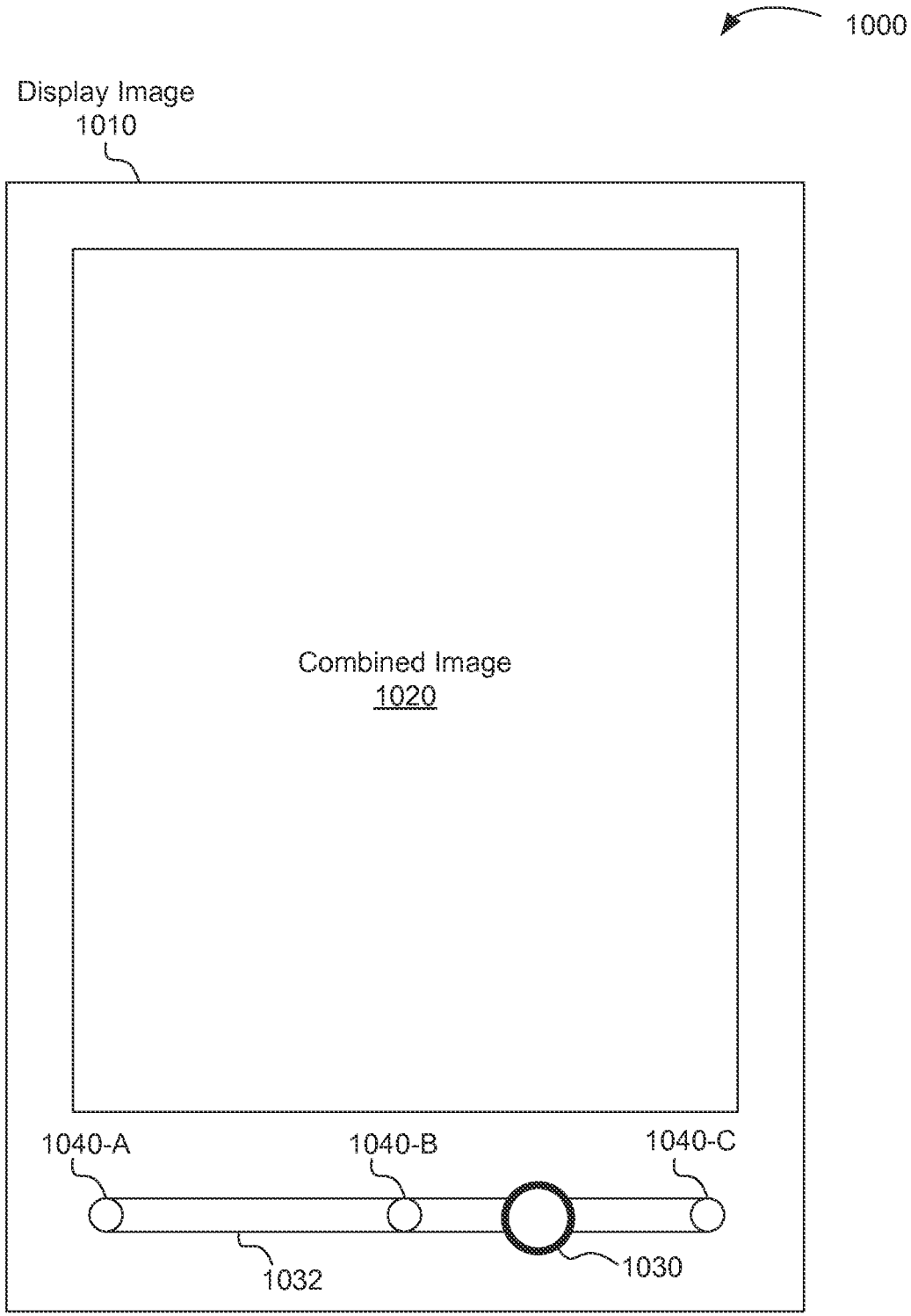
1000
Display Image
1010
Combined Image
1020
1040-A
1040-B
1040-C
1032
1030

Figure 10

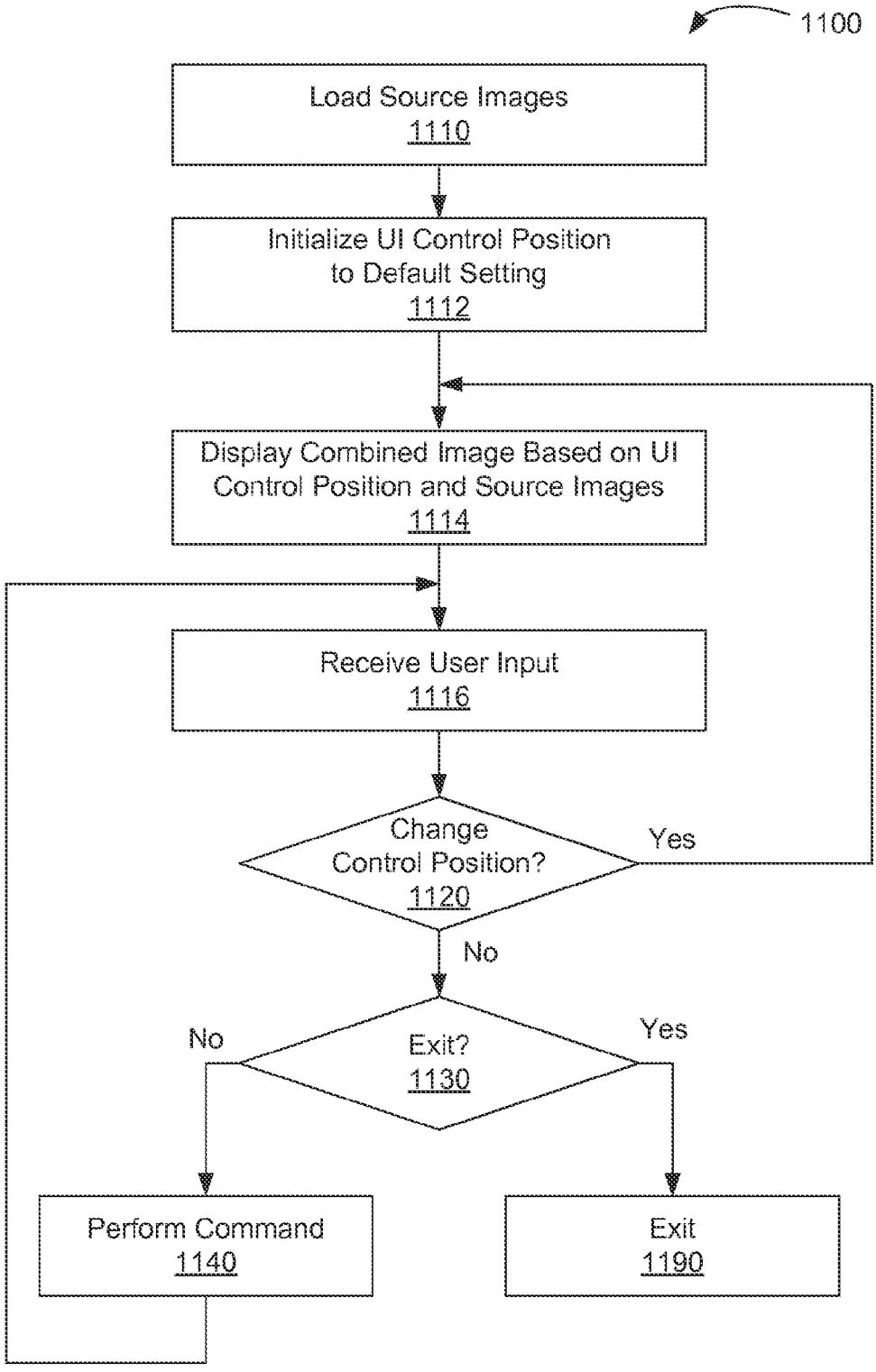
1100
Load Source Images
1110
Initialize UI Control Position
to Default Setting
1112
Display Combined Image Based on UI
Control Position and Source Images
1114
Receive User Input
1116
Change
Control Position?
1120
Yes
No
Exit?
1130
No
Yes
Perform Command
1140
Exit
1190

Figure 11

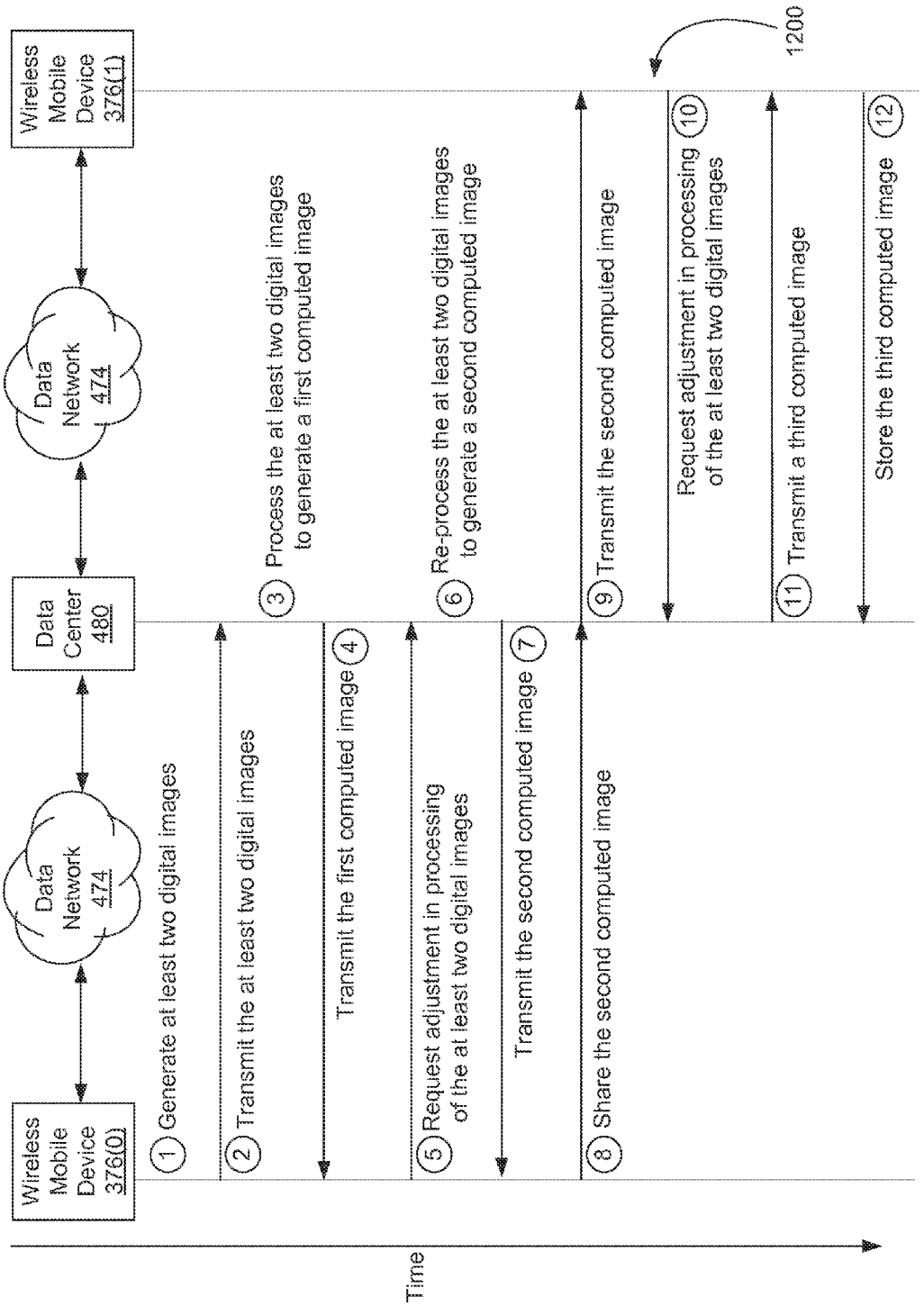
Wireless Mobile Device 376(0)
Data Network 474
Data Center 480
Data Network 474
Wireless Mobile Device 376(1)
1200
Time
(1) Generate at least two digital images
(2) Transmit the at least two digital images
(3) Process the at least two digital images to generate a first computed image
(4) Transmit the first computed image
(5) Request adjustment in processing of the at least two digital images
(6) Re-process the at least two digital images to generate a second computed image
(7) Transmit the second computed image
(8) Share the second computed image
(9) Transmit the second computed image
(10) Request adjustment in processing of the at least two digital images
(11) Transmit a third computed image
(12) Store the third computed image

Figure 12

IMAGE SENSOR APPARATUS AND METHOD FOR OBTAINING MULTIPLE EXPOSURES WITH ZERO INTERFRAME TIME

RELATED APPLICATIONS

This application is related to the following U.S. Patent Applications, the entire disclosures being incorporated by reference herein: Application Ser. No. 13/999,678, filed Mar. 14, 2014, entitled "SYSTEMS AND METHODS FOR DIGITAL IMAGE SENSOR"; Application Ser. No. 14/534,068, filed Nov. 5, 2014, entitled "SYSTEMS AND METHODS FOR HIGH-DYNAMIC RANGE IMAGES"; Application Ser. No. 14/534,089, filed Nov. 5, 2014, entitled "IMAGE SENSOR APPARATUS AND METHOD FOR SIMULTANEOUSLY CAPTURING MULTIPLE IMAGES"; Application Ser. No. 14/535,274, filed Nov. 6, 2014, entitled "IMAGE SENSOR APPARATUS AND METHOD FOR SIMULTANEOUSLY CAPTURING FLASH AND AMBIENT ILLUMINATED IMAGES"; Application Ser. No. 14/535,279, filed Nov. 6, 2014, entitled "IMAGE SENSOR APPARATUS AND METHOD FOR OBTAINING LOW-NOISE, HIGH-SPEED CAPTURES OF A PHOTOGRAPHIC SCENE"; and Application Ser. No. 14/536,524, filed Nov. 7, 2014, entitled "SYSTEMS AND METHODS FOR GENERATING A HIGH-DYNAMIC RANGE (HDR) PIXEL STREAM."

FIELD OF THE INVENTION

The present invention relates to photographic systems, and more particularly to an image sensor apparatus and method for obtaining multiple exposures with zero interframe time.

BACKGROUND

Traditional digital photography systems are inherently limited by the dynamic range of a capturing image sensor. One solution to such limitation is the use of high dynamic-range (HDR) photography. HDR photography involves capturing multiple exposures of a same scene, where each of the exposures is metered differently, and then merging the multiple captures to create an image with a larger dynamic range.

SUMMARY

A system, method, and computer program product are provided for obtaining multiple exposures with zero interframe time. In use, a first an analog signal associated with an image is received from at least one pixel of an image sensor. Next, a first amplified analog signal associated with the image is generated by amplifying the analog signal utilizing a first gain. Further, a second amplified analog signal associated with the image is generated by amplifying the analog signal utilizing a second gain. Finally, the first amplified analog signal and the second amplified analog signal are transmitted.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary system for obtaining multiple exposures with zero interframe time, in accordance with one possible embodiment.

FIG. **2** illustrates an exemplary method carried out for obtaining multiple exposures with zero interframe time, in accordance with one embodiment.

FIG. **3**A illustrates a digital photographic system configured to obtain multiple exposures with zero interframe time, in accordance with an embodiment.

FIG. **3**B illustrates a processor complex within a digital photographic system, according to one embodiment.

FIG. **3**C illustrates a digital camera, in accordance with an embodiment.

FIG. **3**D illustrates a wireless mobile device, in accordance with another embodiment.

FIG. **3**E illustrates a camera module configured to sample an image, according to one embodiment.

FIG. **3**F illustrates a camera module configured to sample an image, according to another embodiment.

FIG. **3**G illustrates a camera module in communication with an application processor, in accordance with an embodiment.

FIG. **4** illustrates a network service system, in accordance with another embodiment.

FIGS. **5**A-**5**E illustrate systems for converting optical scene information to an electronic representation of a photographic scene, in accordance with other embodiments.

FIG. **6** illustrates a system for converting analog pixel data to digital pixel data, in accordance with an embodiment.

FIG. **7** illustrates a system for converting analog pixel data of an analog signal to digital pixel data, in accordance with another embodiment.

FIG. **8** illustrates various timing configurations for amplifying analog signals, in accordance with other embodiments.

FIG. **9** illustrates a system for converting in parallel analog pixel data to multiple signals of digital pixel data, in accordance with one embodiment.

FIG. **10** illustrates a user interface system for generating a combined image, according to an embodiment.

FIG. **11** is a flow diagram of method steps for generating a combined image, according to one embodiment.

FIG. **12** illustrates a message sequence for generating a combined image utilizing a network, according to another embodiment.

DETAILED DESCRIPTION

FIG. **1** illustrates a system **100** for obtaining multiple exposures with zero interframe time, in accordance with one possible embodiment. As an option, the system **100** may be implemented in the context of any of the Figures disclosed herein. Of course, however, the system **100** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

As shown, a signal amplifier **133** receives an analog signal **104** from an image sensor **132**. In response to receiving the analog signal **104**, the signal amplifier **133** amplifies the analog signal **104** utilizing a first gain, and transmits a first amplified analog signal **106**. Further, in response to receiving the analog signal **104**, the signal amplifier **133** also amplifies the analog signal **104** utilizing a second gain, and transmits a second amplified analog signal **108**.

In one specific embodiment, the analog signal **106** and the analog signal **108** are transmitted on a common electrical interconnect. In alternative embodiments, the analog signal **106** and the analog signal **108** are transmitted on different electrical interconnects.

In one embodiment, the analog signal **104** generated by image sensor **132** includes an electronic representation of an optical image that has been focused on the image sensor **132**. In such an embodiment, the optical image may be focused on the image sensor **132** by a lens. The electronic representation of the optical image may comprise spatial color intensity

information, which may include different color intensity samples (e.g. red, green, and blue light, etc.). In other embodiments, the spatial color intensity information may also include samples for white light. In one embodiment, the optical image may be an optical image of a photographic scene.

In one embodiment, the image sensor **132** may comprise a complementary metal oxide semiconductor (CMOS) image sensor, or charge-coupled device (CCD) image sensor, or any other technically feasible form of image sensor.

In an embodiment, the signal amplifier **133** may include a transimpedance amplifier (TIA), which may be dynamically configured, such as by digital gain values, to provide a selected gain to the analog signal **104**. For example, a TIA could be configured to apply a first gain to the analog signal. The same TIA could then be configured to subsequently apply a second gain to the analog signal. In other embodiments, the gain may be specified to the signal amplifier **133** as a digital value. Further, the specified gain value may be based on a specified sensitivity or ISO. The specified sensitivity may be specified by a user of a photographic system, or instead may be set by software or hardware of the photographic system, or some combination of the foregoing working in concert.

In one embodiment, the signal amplifier **133** includes a single amplifier. In such an embodiment, the amplified analog signals **106** and **108** are transmitted or output in sequence. For example, in one embodiment, the output may occur through a common electrical interconnect. For example, the amplified analog signal **106** may first be transmitted, and then the amplified analog signal **108** may subsequently be transmitted. In another embodiment, the signal amplifier **133** may include a plurality of amplifiers. In such an embodiment, the amplifier **133** may transmit the amplified analog signal **106** in parallel with the amplified analog signal **108**. To this end, the analog signal **106** may be amplified utilizing the first gain in serial with the amplification of the analog signal **108** utilizing the second gain, or the analog signal **106** may be amplified utilizing the first gain in parallel with the amplification of the analog signal **108** utilizing the second gain. In one embodiment, the amplified analog signals **106** and **108** each include gain-adjusted analog pixel data.

Each instance of gain-adjusted analog pixel data may be converted to digital pixel data by subsequent processes and/or hardware. For example, the amplified analog signal **106** may subsequently be converted to a first digital signal comprising a first set of digital pixel data representative of the optical image that has been focused on the image sensor **132**. Further, the amplified analog signal **108** may subsequently or concurrently be converted to a second digital signal comprising a second set of digital pixel data representative of the optical image that has been focused on the image sensor **132**. In one embodiment, any differences between the first set of digital pixel data and the second set of digital pixel data are a function of a difference between the first gain and the second gain applied by the signal amplifier **133**. Further, each set of digital pixel data may include a digital image of the photographic scene. Thus, the amplified analog signals **106** and **108** may be used to generate two different digital images of the photographic scene. Furthermore, in one embodiment, each of the two different digital images may represent a different exposure level.

FIG. **2** illustrates a method **200** for obtaining multiple exposures with zero interframe time, in accordance with one embodiment. As an option, the method **200** may be carried out in the context of any of the Figures disclosed herein. Of course, however, the method **200** may be carried out in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

As shown in operation **202**, an analog signal associated with an image is received from at least one pixel of an image sensor. In the context of the present embodiment, the analog signal may include analog pixel data for at least one pixel of an image sensor. In one embodiment, the analog signal may include analog pixel data for every pixel of an image sensor. In another embodiment, each pixel of an image sensor may include a plurality of photodiodes. In such an embodiment, the analog pixel data received in the analog signal may include an analog value for each photodiode of each pixel of the image sensor. Each analog value may be representative of a light intensity measured at the photodiode associated with the analog value. Accordingly, an analog signal may be a set of spatially discrete intensity samples, each represented by continuous analog values, and analog pixel data may be analog signal values associated with one or more given pixels.

Additionally, as shown in operation **204**, a first amplified analog signal associated with the image is generated by amplifying the analog signal utilizing a first gain, and a second amplified analog signal associated with the image is generated by amplifying the analog signal utilizing a second gain. Accordingly, the analog signal is amplified utilizing both the first gain and the second gain, resulting in the first amplified analog signal and the second amplified analog signal, respectively. In one embodiment, the first amplified analog signal may include first gain-adjusted analog pixel data. In such an embodiment, the second amplified analog signal may include second gain-adjusted analog pixel data. In accordance with one embodiment, the analog signal may be amplified utilizing the first gain simultaneously with the amplification of the analog signal utilizing the second gain. In another embodiment, the analog signal may be amplified utilizing the first gain during a period of time other than when the analog signal is amplified utilizing the second gain. For example, the first gain and the second gain may be applied to the analog signal in sequence. In one embodiment, a sequence for applying the gains to the analog signal may be predetermined.

Further, as shown in operation **206**, the first amplified analog signal and the second amplified analog signal are both transmitted, such that multiple amplified analog signals are transmitted based on the analog signal associated with the image. In the context of one embodiment, the first amplified analog signal and the second amplified analog signal are transmitted in sequence. For example, the first amplified analog signal may be transmitted prior to the second amplified analog signal. In another embodiment, the first amplified analog signal and the second amplified signal may be transmitted in parallel.

The embodiments disclosed herein advantageously enable a camera module to sample images comprising an image stack with lower (e.g. at or near zero, etc.) inter-sample time (e.g. interframe, etc.) than conventional techniques. In certain embodiments, images comprising the image stack are effectively sampled during overlapping time intervals, which may reduce inter-sample time to zero. In other embodiments, the camera module may sample images in coordination with the strobe unit to reduce inter-sample time between an image sampled without strobe illumination and an image sampled with strobe illumination.

More illustrative information will now be set forth regarding various optional architectures and uses in which the foregoing method may or may not be implemented, per the desires of the user. It should be strongly noted that the following information is set forth for illustrative purposes and should not be construed as limiting in any manner. Any of the

following features may be optionally incorporated with or without the exclusion of other features described.

FIG. **3A** illustrates a digital photographic system **300**, in accordance with one embodiment. As an option, the digital photographic system **300** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the digital photographic system **300** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

As shown, the digital photographic system **300** may include a processor complex **310** coupled to a camera module **330** via an interconnect **334**. In one embodiment, the processor complex **310** is coupled to a strobe unit **336**. The digital photographic system **300** may also include, without limitation, a display unit **312**, a set of input/output devices **314**, non-volatile memory **316**, volatile memory **318**, a wireless unit **340**, and sensor devices **342**, each coupled to the processor complex **310**. In one embodiment, a power management subsystem **320** is configured to generate appropriate power supply voltages for each electrical load element within the digital photographic system **300**. A battery **322** may be configured to supply electrical energy to the power management subsystem **320**. The battery **322** may implement any technically feasible energy storage system, including primary or rechargeable battery technologies. Of course, in other embodiments, additional or fewer features, units, devices, sensors, or subsystems may be included in the system.

In one embodiment, a strobe unit **336** may be integrated into the digital photographic system **300** and configured to provide strobe illumination **350** during an image sample event performed by the digital photographic system **300**. In another embodiment, a strobe unit **336** may be implemented as an independent device from the digital photographic system **300** and configured to provide strobe illumination **350** during an image sample event performed by the digital photographic system **300**. The strobe unit **336** may comprise one or more LED devices, a gas-discharge illuminator (e.g. a Xenon strobe device, a Xenon flash lamp, etc.), or any other technically feasible illumination device. In certain embodiments, two or more strobe units are configured to synchronously generate strobe illumination in conjunction with sampling an image. In one embodiment, the strobe unit **336** is controlled through a strobe control signal **338** to either emit the strobe illumination **350** or not emit the strobe illumination **350**. The strobe control signal **338** may be implemented using any technically feasible signal transmission protocol. The strobe control signal **338** may indicate a strobe parameter (e.g. strobe intensity, strobe color, strobe time, etc.), for directing the strobe unit **336** to generate a specified intensity and/or color of the strobe illumination **350**. The strobe control signal **338** may be generated by the processor complex **310**, the camera module **330**, or by any other technically feasible combination thereof. In one embodiment, the strobe control signal **338** is generated by a camera interface unit within the processor complex **310** and transmitted to both the strobe unit **336** and the camera module **330** via the interconnect **334**. In another embodiment, the strobe control signal **338** is generated by the camera module **330** and transmitted to the strobe unit **336** via the interconnect **334**.

Optical scene information **352**, which may include at least a portion of the strobe illumination **350** reflected from objects in the photographic scene, is focused as an optical image onto an image sensor **332** within the camera module **330**. The image sensor **332** generates an electronic representation of the optical image. The electronic representation comprises spatial color intensity information, which may include different color intensity samples (e.g. red, green, and blue light, etc.). In other embodiments, the spatial color intensity information may also include samples for white light. The electronic representation is transmitted to the processor complex **310** via the interconnect **334**, which may implement any technically feasible signal transmission protocol.

In one embodiment, input/output devices **314** may include, without limitation, a capacitive touch input surface, a resistive tablet input surface, one or more buttons, one or more knobs, light-emitting devices, light detecting devices, sound emitting devices, sound detecting devices, or any other technically feasible device for receiving user input and converting the input to electrical signals, or converting electrical signals into a physical signal. In one embodiment, the input/output devices **314** include a capacitive touch input surface coupled to a display unit **312**. A touch entry display system may include the display unit **312** and a capacitive touch input surface, also coupled to processor complex **310**.

Additionally, in other embodiments, non-volatile (NV) memory **316** is configured to store data when power is interrupted. In one embodiment, the NV memory **316** comprises one or more flash memory devices (e.g. ROM, PCM, FeRAM, FRAM, PRAM, MRAM, NRAM, etc.). The NV memory **316** comprises a non-transitory computer-readable medium, which may be configured to include programming instructions for execution by one or more processing units within the processor complex **310**. The programming instructions may implement, without limitation, an operating system (OS), UI software modules, image processing and storage software modules, one or more input/output devices **314** connected to the processor complex **310**, one or more software modules for sampling an image stack through camera module **330**, one or more software modules for presenting the image stack or one or more synthetic images generated from the image stack through the display unit **312**. As an example, in one embodiment, the programming instructions may also implement one or more software modules for merging images or portions of images within the image stack, aligning at least portions of each image within the image stack, or a combination thereof. In another embodiment, the processor complex **310** may be configured to execute the programming instructions, which may implement one or more software modules operable to create a high dynamic range (HDR) image.

Still yet, in one embodiment, one or more memory devices comprising the NV memory **316** may be packaged as a module configured to be installed or removed by a user. In one embodiment, volatile memory **318** comprises dynamic random access memory (DRAM) configured to temporarily store programming instructions, image data such as data associated with an image stack, and the like, accessed during the course of normal operation of the digital photographic system **300**. Of course, the volatile memory may be used in any manner and in association with any other input/output device **314** or sensor device **342** attached to the process complex **310**.

In one embodiment, sensor devices **342** may include, without limitation, one or more of an accelerometer to detect motion and/or orientation, an electronic gyroscope to detect motion and/or orientation, a magnetic flux detector to detect orientation, a global positioning system (GPS) module to detect geographic position, or any combination thereof. Of course, other sensors, including but not limited to a motion detection sensor, a proximity sensor, an RGB light sensor, a gesture sensor, a 3-D input image sensor, a pressure sensor, and an indoor position sensor, may be integrated as sensor devices. In one embodiment, the sensor devices may be one example of input/output devices **314**.

Wireless unit **340** may include one or more digital radios configured to send and receive digital data. In particular, the wireless unit **340** may implement wireless standards (e.g. WiFi, Bluetooth, NFC, etc.), and may implement digital cellular telephony standards for data communication (e.g. CDMA, 3G, 4G, LTE, LTE-Advanced, etc.). Of course, any wireless standard or digital cellular telephony standards may be used.

In one embodiment, the digital photographic system **300** is configured to transmit one or more digital photographs to a network-based (online) or "cloud-based" photographic media service via the wireless unit **340**. The one or more digital photographs may reside within either the NV memory **316** or the volatile memory **318**, or any other memory device associated with the processor complex **310**. In one embodiment, a user may possess credentials to access an online photographic media service and to transmit one or more digital photographs for storage to, retrieval from, and presentation by the online photographic media service. The credentials may be stored or generated within the digital photographic system **300** prior to transmission of the digital photographs. The online photographic media service may comprise a social networking service, photograph sharing service, or any other network-based service that provides storage of digital photographs, processing of digital photographs, transmission of digital photographs, sharing of digital photographs, or any combination thereof. In certain embodiments, one or more digital photographs are generated by the online photographic media service based on image data (e.g. image stack, HDR image stack, image package, etc.) transmitted to servers associated with the online photographic media service. In such embodiments, a user may upload one or more source images from the digital photographic system **300** for processing by the online photographic media service.

In one embodiment, the digital photographic system **300** comprises at least one instance of a camera module **330**. In another embodiment, the digital photographic system **300** comprises a plurality of camera modules **330**. Such an embodiment may also include at least one strobe unit **336** configured to illuminate a photographic scene, sampled as multiple views by the plurality of camera modules **330**. The plurality of camera modules **330** may be configured to sample a wide angle view (e.g., greater than forty-five degrees of sweep among cameras) to generate a panoramic photograph. In one embodiment, a plurality of camera modules **330** may be configured to sample two or more narrow angle views (e.g., less than forty-five degrees of sweep among cameras) to generate a stereoscopic photograph. In other embodiments, a plurality of camera modules **330** may be configured to generate a 3-D image or to otherwise display a depth perspective (e.g. a z-component, etc.) as shown on the display unit **312** or any other display device.

In one embodiment, a display unit **312** may be configured to display a two-dimensional array of pixels to form an image for display. The display unit **312** may comprise a liquid-crystal (LCD) display, a light-emitting diode (LED) display, an organic LED display, or any other technically feasible type of display. In certain embodiments, the display unit **312** may be able to display a narrower dynamic range of image intensity values than a complete range of intensity values sampled from a photographic scene, such as within a single HDR image or over a set of two or more images comprising a multiple exposure or HDR image stack. In one embodiment, images comprising an image stack may be merged according to any technically feasible HDR blending technique to generate a synthetic image for display within dynamic range constraints of the display unit **312**. In one embodiment, the limited dynamic range may specify an eight-bit per color channel binary representation of corresponding color intensities. In other embodiments, the limited dynamic range may specify more than eight-bits (e.g., 10 bits, 12 bits, or 14 bits, etc.) per color channel binary representation.

FIG. **3**B illustrates a processor complex **310** within the digital photographic system **300** of FIG. **3**A, in accordance with one embodiment. As an option, the processor complex **310** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the processor complex **310** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

As shown, the processor complex **310** includes a processor subsystem **360** and may include a memory subsystem **362**. In one embodiment, processor complex **310** may comprise a system on a chip (SoC) device that implements processor subsystem **360**, and memory subsystem **362** comprises one or more DRAM devices coupled to the processor subsystem **360**. In another embodiment, the processor complex **310** may comprise a multi-chip module (MCM) encapsulating the SoC device and the one or more DRAM devices comprising the memory subsystem **362**.

The processor subsystem **360** may include, without limitation, one or more central processing unit (CPU) cores **370**, a memory interface **380**, input/output interfaces unit **384**, and a display interface unit **382**, each coupled to an interconnect **374**. The one or more CPU cores **370** may be configured to execute instructions residing within the memory subsystem **362**, volatile memory **318**, NV memory **316**, or any combination thereof. Each of the one or more CPU cores **370** may be configured to retrieve and store data through interconnect **374** and the memory interface **380**. In one embodiment, each of the one or more CPU cores **370** may include a data cache, and an instruction cache. Additionally, two or more of the CPU cores **370** may share a data cache, an instruction cache, or any combination thereof. In one embodiment, a cache hierarchy is implemented to provide each CPU core **370** with a private cache layer, and a shared cache layer.

In some embodiments, processor subsystem **360** may include one or more graphics processing unit (GPU) cores **372**. Each GPU core **372** may comprise a plurality of multi-threaded execution units that may be programmed to implement, without limitation, graphics acceleration functions. In various embodiments, the GPU cores **372** may be configured to execute multiple thread programs according to well-known standards (e.g. OpenGL™, WebGL™, OpenCL™, CUDA™, etc.), and/or any other programmable rendering graphic standard. In certain embodiments, at least one GPU core **372** implements at least a portion of a motion estimation function, such as a well-known Harris detector or a well-known Hessian-Laplace detector. Such a motion estimation function may be used at least in part to align images or portions of images within an image stack. For example, in one embodiment, an HDR image may be compiled based on an image stack, where two or more images are first aligned prior to compiling the HDR image.

As shown, the interconnect **374** is configured to transmit data between and among the memory interface **380**, the display interface unit **382**, the input/output interfaces unit **384**, the CPU cores **370**, and the GPU cores **372**. In various embodiments, the interconnect **374** may implement one or more buses, one or more rings, a cross-bar, a mesh, or any other technically feasible data transmission structure or technique. The memory interface **380** is configured to couple the memory subsystem **362** to the interconnect **374**. The memory interface **380** may also couple NV memory **316**, volatile

memory **318**, or any combination thereof to the interconnect **374**. The display interface unit **382** may be configured to couple a display unit **312** to the interconnect **374**. The display interface unit **382** may implement certain frame buffer functions (e.g. frame refresh, etc.). Alternatively, in another embodiment, the display unit **312** may implement certain frame buffer functions (e.g. frame refresh, etc.). The input/output interfaces unit **384** may be configured to couple various input/output devices to the interconnect **374**.

In certain embodiments, a camera module **330** is configured to store exposure parameters for sampling each image associated with an image stack. For example, in one embodiment, when directed to sample a photographic scene, the camera module **330** may sample a set of images comprising the image stack according to stored exposure parameters. A software module comprising programming instructions executing within a processor complex **310** may generate and store the exposure parameters prior to directing the camera module **330** to sample the image stack. In other embodiments, the camera module **330** may be used to meter an image or an image stack, and the software module comprising programming instructions executing within a processor complex **310** may generate and store metering parameters prior to directing the camera module **330** to capture the image. Of course, the camera module **330** may be used in any manner in combination with the processor complex **310**.

In one embodiment, exposure parameters associated with images comprising the image stack may be stored within an exposure parameter data structure that includes exposure parameters for one or more images. In another embodiment, a camera interface unit (not shown in FIG. **3**B) within the processor complex **310** may be configured to read exposure parameters from the exposure parameter data structure and to transmit associated exposure parameters to the camera module **330** in preparation of sampling a photographic scene. After the camera module **330** is configured according to the exposure parameters, the camera interface may direct the camera module **330** to sample the photographic scene; the camera module **330** may then generate a corresponding image stack. The exposure parameter data structure may be stored within the camera interface unit, a memory circuit within the processor complex **310**, volatile memory **318**, NV memory **316**, the camera module **330**, or within any other technically feasible memory circuit. Further, in another embodiment, a software module executing within processor complex **310** may generate and store the exposure parameter data structure.

FIG. **3**C illustrates a digital camera **302**, in accordance with one embodiment. As an option, the digital camera **302** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the digital camera **302** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In one embodiment, the digital camera **302** may be configured to include a digital photographic system, such as digital photographic system **300** of FIG. **3**A. As shown, the digital camera **302** includes a camera module **330**, which may include optical elements configured to focus optical scene information representing a photographic scene onto an image sensor, which may be configured to convert the optical scene information to an electronic representation of the photographic scene.

Additionally, the digital camera **302** may include a strobe unit **336**, and may include a shutter release button **315** for triggering a photographic sample event, whereby digital camera **302** samples one or more images comprising the electronic representation. In other embodiments, any other technically feasible shutter release mechanism may trigger the photographic sample event (e.g. such as a timer trigger or remote control trigger, etc.).

FIG. **3**D illustrates a wireless mobile device **376**, in accordance with one embodiment. As an option, the mobile device **376** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the mobile device **376** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In one embodiment, the mobile device **376** may be configured to include a digital photographic system (e.g. such as digital photographic system **300** of FIG. **3**A), which is configured to sample a photographic scene. In various embodiments, a camera module **330** may include optical elements configured to focus optical scene information representing the photographic scene onto an image sensor, which may be configured to convert the optical scene information to an electronic representation of the photographic scene. Further, a shutter release command may be generated through any technically feasible mechanism, such as a virtual button, which may be activated by a touch gesture on a touch entry display system comprising display unit **312**, or a physical button, which may be located on any face or surface of the mobile device **376**. Of course, in other embodiments, any number of other buttons, external inputs/outputs, or digital inputs/outputs may be included on the mobile device **376**, and which may be used in conjunction with the camera module **330**.

As shown, in one embodiment, a touch entry display system comprising display unit **312** is disposed on the opposite side of mobile device **376** from camera module **330**. In certain embodiments, the mobile device **376** includes a user-facing camera module **331** and may include a user-facing strobe unit (not shown). Of course, in other embodiments, the mobile device **376** may include any number of user-facing camera modules or rear-facing camera modules, as well as any number of user-facing strobe units or rear-facing strobe units.

In some embodiments, the digital camera **302** and the mobile device **376** may each generate and store a synthetic image based on an image stack sampled by camera module **330**. The image stack may include one or more images sampled under ambient lighting conditions, one or more images sampled under strobe illumination from strobe unit **336**, or a combination thereof.

FIG. **3**E illustrates camera module **330**, in accordance with one embodiment. As an option, the camera module **330** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the camera module **330** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In one embodiment, the camera module **330** may be configured to control strobe unit **336** through strobe control signal **338**. As shown, a lens **390** is configured to focus optical scene information **352** onto image sensor **332** to be sampled. In one embodiment, image sensor **332** advantageously controls detailed timing of the strobe unit **336** though the strobe control signal **338** to reduce inter-sample time between an image sampled with the strobe unit **336** enabled, and an image sampled with the strobe unit **336** disabled. For example, the image sensor **332** may enable the strobe unit **336** to emit strobe illumination **350** less than one microsecond (or any desired length) after image sensor **332** completes an exposure time associated with sampling an ambient image and prior to sampling a strobe image.

In other embodiments, the strobe illumination **350** may be configured based on a desired one or more target points. For example, in one embodiment, the strobe illumination **350** may light up an object in the foreground, and depending on the length of exposure time, may also light up an object in the background of the image. In one embodiment, once the strobe unit **336** is enabled, the image sensor **332** may then immediately begin exposing a strobe image. The image sensor **332** may thus be able to directly control sampling operations, including enabling and disabling the strobe unit **336** associated with generating an image stack, which may comprise at least one image sampled with the strobe unit **336** disabled, and at least one image sampled with the strobe unit **336** either enabled or disabled. In one embodiment, data comprising the image stack sampled by the image sensor **332** is transmitted via interconnect **334** to a camera interface unit **386** within processor complex **310**. In some embodiments, the camera module **330** may include an image sensor controller, which may be configured to generate the strobe control signal **338** in conjunction with controlling operation of the image sensor **332**.

FIG. **3**F illustrates a camera module **330**, in accordance with one embodiment. As an option, the camera module **330** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the camera module **330** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In one embodiment, the camera module **330** may be configured to sample an image based on state information for strobe unit **336**. The state information may include, without limitation, one or more strobe parameters (e.g. strobe intensity, strobe color, strobe time, etc.), for directing the strobe unit **336** to generate a specified intensity and/or color of the strobe illumination **350**. In one embodiment, commands for configuring the state information associated with the strobe unit **336** may be transmitted through a strobe control signal **338**, which may be monitored by the camera module **330** to detect when the strobe unit **336** is enabled. For example, in one embodiment, the camera module **330** may detect when the strobe unit **336** is enabled or disabled within a microsecond or less of the strobe unit **336** being enabled or disabled by the strobe control signal **338**. To sample an image requiring strobe illumination, a camera interface unit **386** may enable the strobe unit **336** by sending an enable command through the strobe control signal **338**. In one embodiment, the camera interface unit **386** may be included as an interface of input/output interfaces **384** in a processor subsystem **360** of the processor complex **310** of FIG. **3**B The enable command may comprise a signal level transition, a data packet, a register write, or any other technically feasible transmission of a command. The camera module **330** may sense that the strobe unit **336** is enabled and then cause image sensor **332** to sample one or more images requiring strobe illumination while the strobe unit **336** is enabled. In such an implementation, the image sensor **332** may be configured to wait for an enable signal destined for the strobe unit **336** as a trigger signal to begin sampling a new exposure.

In one embodiment, camera interface unit **386** may transmit exposure parameters and commands to camera module **330** through interconnect **334**. In certain embodiments, the camera interface unit **386** may be configured to directly control strobe unit **336** by transmitting control commands to the strobe unit **336** through strobe control signal **338**. By directly controlling both the camera module **330** and the strobe unit **336**, the camera interface unit **386** may cause the camera module **330** and the strobe unit **336** to perform their respective operations in precise time synchronization. In one embodiment, precise time synchronization may be less than five hundred microseconds of event timing error. Additionally, event timing error may be a difference in time from an intended event occurrence to the time of a corresponding actual event occurrence.

In another embodiment, camera interface unit **386** may be configured to accumulate statistics while receiving image data from camera module **330**. In particular, the camera interface unit **386** may accumulate exposure statistics for a given image while receiving image data for the image through interconnect **334**. Exposure statistics may include, without limitation, one or more of an intensity histogram, a count of over-exposed pixels, a count of under-exposed pixels, an intensity-weighted sum of pixel intensity, or any combination thereof. The camera interface unit **386** may present the exposure statistics as memory-mapped storage locations within a physical or virtual address space defined by a processor, such as one or more of CPU cores **370**, within processor complex **310**. In one embodiment, exposure statistics reside in storage circuits that are mapped into a memory-mapped register space, which may be accessed through the interconnect **334**. In other embodiments, the exposure statistics are transmitted in conjunction with transmitting pixel data for a captured image. For example, the exposure statistics for a given image may be transmitted as in-line data, following transmission of pixel intensity data for the captured image. Exposure statistics may be calculated, stored, or cached within the camera interface unit **386**.

In one embodiment, camera interface unit **386** may accumulate color statistics for estimating scene white-balance. Any technically feasible color statistics may be accumulated for estimating white balance, such as a sum of intensities for different color channels comprising red, green, and blue color channels. The sum of color channel intensities may then be used to perform a white-balance color correction on an associated image, according to a white-balance model such as a gray-world white-balance model. In other embodiments, curve-fitting statistics are accumulated for a linear or a quadratic curve fit used for implementing white-balance correction on an image.

In one embodiment, camera interface unit **386** may accumulate spatial color statistics for performing color-matching between or among images, such as between or among an ambient image and one or more images sampled with strobe illumination. As with the exposure statistics, the color statistics may be presented as memory-mapped storage locations within processor complex **310**. In one embodiment, the color statistics are mapped in a memory-mapped register space, which may be accessed through interconnect **334**, within processor subsystem **360**. In other embodiments, the color statistics may be transmitted in conjunction with transmitting pixel data for a captured image. For example, in one embodiment, the color statistics for a given image may be transmitted as in-line data, following transmission of pixel intensity data for the image. Color statistics may be calculated, stored, or cached within the camera interface **386**.

In one embodiment, camera module **330** may transmit strobe control signal **338** to strobe unit **336**, enabling the strobe unit **336** to generate illumination while the camera module **330** is sampling an image. In another embodiment, camera module **330** may sample an image illuminated by strobe unit **336** upon receiving an indication signal from camera interface unit **386** that the strobe unit **336** is enabled. In yet another embodiment, camera module **330** may sample an image illuminated by strobe unit **336** upon detecting strobe illumination within a photographic scene via a rapid rise in

scene illumination. In one embodiment, a rapid rise in scene illumination may include at least a rate of increasing intensity consistent with that of enabling strobe unit **336**. In still yet another embodiment, camera module **330** may enable strobe unit **336** to generate strobe illumination while sampling one image, and disable the strobe unit **336** while sampling a different image.

FIG. **3**G illustrates camera module **330**, in accordance with one embodiment. As an option, the camera module **330** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the camera module **330** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In one embodiment, the camera module **330** may be in communication with an application processor **335**. The camera module **330** is shown to include image sensor **332** in communication with a controller **333**. Further, the controller **333** is shown to be in communication with the application processor **335**.

In one embodiment, the application processor **335** may reside outside of the camera module **330**. As shown, the lens **390** may be configured to focus optical scene information onto image sensor **332** to be sampled. The optical scene information sampled by the image sensor **332** may then be communicated from the image sensor **332** to the controller **333** for at least one of subsequent processing and communication to the application processor **335**. In another embodiment, the controller **333** may control storage of the optical scene information sampled by the image sensor **332**, or storage of processed optical scene information.

In another embodiment, the controller **333** may enable a strobe unit to emit strobe illumination for a short time duration (e.g. less than one microsecond, etc.) after image sensor **332** completes an exposure time associated with sampling an ambient image. Further, the controller **333** may be configured to generate strobe control signal **338** in conjunction with controlling operation of the image sensor **332**.

In one embodiment, the image sensor **332** may be a complementary metal oxide semiconductor (CMOS) sensor or a charge-coupled device (CCD) sensor. In another embodiment, the controller **333** and the image sensor **332** may be packaged together as an integrated system or integrated circuit. In yet another embodiment, the controller **333** and the image sensor **332** may comprise discrete packages. In one embodiment, the controller **333** may provide circuitry for receiving optical scene information from the image sensor **332**, processing of the optical scene information, timing of various functionalities, and signaling associated with the application processor **335**. Further, in another embodiment, the controller **333** may provide circuitry for control of one or more of exposure, shuttering, white balance, and gain adjustment. Processing of the optical scene information by the circuitry of the controller **333** may include one or more of gain application, amplification, and analog-to-digital conversion. After processing the optical scene information, the controller **333** may transmit corresponding digital pixel data, such as to the application processor **335**.

In one embodiment, the application processor **335** may be implemented on processor complex **310** and at least one of volatile memory **318** and NV memory **316**, or any other memory device and/or system. The application processor **335** may be previously configured for processing of received optical scene information or digital pixel data communicated from the camera module **330** to the application processor **335**.

FIG. **4** illustrates a network service system **400**, in accordance with one embodiment. As an option, the network service system **400** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the network service system **400** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In one embodiment, the network service system **400** may be configured to provide network access to a device implementing a digital photographic system. As shown, network service system **400** includes a wireless mobile device **376**, a wireless access point **472**, a data network **474**, data center **480**, and a data center **481**. The wireless mobile device **376** may communicate with the wireless access point **472** via a digital radio link **471** to send and receive digital data, including data associated with digital images. The wireless mobile device **376** and the wireless access point **472** may implement any technically feasible transmission techniques for transmitting digital data via digital a radio link **471**. In certain embodiments, one or more of data centers **480**, **481** may be implemented using virtual constructs so that each system and subsystem within a given data center **480**, **481** may comprise virtual machines configured to perform specified data processing and network tasks. In other implementations, one or more of data centers **480**, **481** may be physically distributed over a plurality of physical sites.

The wireless mobile device **376** may comprise a smart phone configured to include a digital camera, a digital camera configured to include wireless network connectivity, a reality augmentation device, a laptop configured to include a digital camera and wireless network connectivity, or any other technically feasible computing device configured to include a digital photographic system and wireless network connectivity.

In various embodiments, the wireless access point **472** may be configured to communicate with wireless mobile device **376** via the digital radio link **471** and to communicate with the data network **474** via any technically feasible transmission media, such as any electrical, optical, or radio transmission media. For example, in one embodiment, wireless access point **472** may communicate with data network **474** through an optical fiber coupled to the wireless access point **472** and to a router system or a switch system within the data network **474**. A network link **475**, such as a wide area network (WAN) link, may be configured to transmit data between the data network **474** and the data center **480**.

In one embodiment, the data network **474** may include routers, switches, long-haul transmission systems, provisioning systems, authorization systems, and any technically feasible combination of communications and operations subsystems configured to convey data between network endpoints, such as between the wireless access point **472** and the data center **480**. In one implementation, a wireless the mobile device **376** may comprise one of a plurality of wireless mobile devices configured to communicate with the data center **480** via one or more wireless access points coupled to the data network **474**.

Additionally, in various embodiments, the data center **480** may include, without limitation, a switch/router **482** and at least one data service system **484**. The switch/router **482** may be configured to forward data traffic between and among a network link **475**, and each data service system **484**. The switch/router **482** may implement any technically feasible transmission techniques, such as Ethernet media layer transmission, layer 2 switching, layer 3 routing, and the like. The switch/router **482** may comprise one or more individual systems configured to transmit data between the data service systems **484** and the data network **474**.

In one embodiment, the switch/router **482** may implement session-level load balancing among a plurality of data service systems **484**. Each data service system **484** may include at least one computation system **488** and may also include one or more storage systems **486**. Each computation system **488** may comprise one or more processing units, such as a central processing unit, a graphics processing unit, or any combination thereof. A given data service system **484** may be implemented as a physical system comprising one or more physically distinct systems configured to operate together. Alternatively, a given data service system **484** may be implemented as a virtual system comprising one or more virtual systems executing on an arbitrary physical system. In certain scenarios, the data network **474** may be configured to transmit data between the data center **480** and another data center **481**, such as through a network link **476**.

In another embodiment, the network service system **400** may include any networked mobile devices configured to implement one or more embodiments of the present invention. For example, in some embodiments, a peer-to-peer network, such as an ad-hoc wireless network, may be established between two different wireless mobile devices. In such embodiments, digital image data may be transmitted between the two wireless mobile devices without having to send the digital image data to a data center **480**.

FIG. **5**A illustrates a system for capturing optical scene information for conversion to an electronic representation of a photographic scene, in accordance with one embodiment. As an option, the system of FIG. **5**A may be implemented in the context of the details of any of the Figures. As shown in FIG. **5**A, a pixel array **510** is in communication with row logic **512** and a column read out circuit **520**. Further, the row logic **512** and the column read out circuit **520** are both in communication with a control unit **514**. Still further, the pixel array **510** is shown to include a plurality of pixels **540**, where each pixel **540** may include four cells, cells **542-545**. In the context of the present description, the pixel array **510** may be included in an image sensor, such as image sensor **132** or image sensor **332** of camera module **330**.

As shown, the pixel array **510** includes a 2-dimensional array of the pixels **540**. For example, in one embodiment, the pixel array **510** may be built to comprise 4,000 pixels **540** in a first dimension, and 3,000 pixels **540** in a second dimension, for a total of 12,000,000 pixels **540** in the pixel array **510**, which may be referred to as a 12 megapixel pixel array. Further, as noted above, each pixel **540** is shown to include four cells **542-545**. In one embodiment, cell **542** may be associated with (e.g. selectively sensitive to, etc.) a first color of light, cell **543** may be associated with a second color of light, cell **544** may be associated with a third color of light, and cell **545** may be associated with a fourth color of light. In one embodiment, each of the first color of light, second color of light, third color of light, and fourth color of light are different colors of light, such that each of the cells **542-545** may be associated with different colors of light. In another embodiment, at least two cells of the cells **542-545** may be associated with a same color of light. For example, the cell **543** and the cell **544** may be associated with the same color of light.

Further, each of the cells **542-545** may be capable of storing an analog value. In one embodiment, each of the cells **542-545** may be associated with a capacitor for storing a charge that corresponds to an accumulated exposure during an exposure time. In such an embodiment, asserting a row select signal to circuitry of a given cell may cause the cell to perform a read operation, which may include, without limitation, generating and transmitting a current that is a function of the stored charge of the capacitor associated with the cell. In one embodiment, prior to a readout operation, current received at the capacitor from an associated photodiode may cause the capacitor, which has been previously charged, to discharge at a rate that is proportional to an incident light intensity detected at the photodiode. The remaining charge of the capacitor of the cell may then be read using the row select signal, where the current transmitted from the cell is an analog value that reflects the remaining charge on the capacitor. To this end, an analog value received from a cell during a readout operation may reflect an accumulated intensity of light detected at a photodiode. The charge stored on a given capacitor, as well as any corresponding representations of the charge, such as the transmitted current, may be referred to herein as a type of analog pixel data. Of course, analog pixel data may include a set of spatially discrete intensity samples, each represented by continuous analog values.

Still further, the row logic **512** and the column read out circuit **520** may work in concert under the control of the control unit **514** to read a plurality of cells **542-545** of a plurality of pixels **540**. For example, the control unit **514** may cause the row logic **512** to assert a row select signal comprising row control signals **530** associated with a given row of pixels **540** to enable analog pixel data associated with the row of pixels to be read. As shown in FIG. **5**A, this may include the row logic **512** asserting one or more row select signals comprising row control signals **530**(**0**) associated with a row **534**(**0**) that includes pixel **540**(**0**) and pixel **540**(*a*). In response to the row select signal being asserted, each pixel **540** on row **534**(**0**) transmits at least one analog value based on charges stored within the cells **542-545** of the pixel **540**. In certain embodiments, cell **542** and cell **543** are configured to transmit corresponding analog values in response to a first row select signal, while cell **544** and cell **545** are configured to transmit corresponding analog values in response to a second row select signal.

In one embodiment, analog values for a complete row of pixels **540** comprising each row **534**(**0**) through **534**(*r*) may be transmitted in sequence to column read out circuit **520** through column signals **532**. In one embodiment, analog values for a complete row or pixels or cells within a complete row of pixels may be transmitted simultaneously. For example, in response to row select signals comprising row control signals **530**(**0**) being asserted, the pixel **540**(**0**) may respond by transmitting at least one analog value from the cells **542-545** of the pixel **540**(**0**) to the column read out circuit **520** through one or more signal paths comprising column signals **532**(**0**); and simultaneously, the pixel **540**(*a*) will also transmit at least one analog value from the cells **542-545** of the pixel **540**(*a*) to the column read out circuit **520** through one or more signal paths comprising column signals **532**(*c*). Of course, one or more analog values may be received at the column read out circuit **520** from one or more other pixels **540** concurrently to receiving the at least one analog value from pixel **540**(**0**) and concurrently receiving the at least one analog value from the pixel **540**(*a*). Together, a set of analog values received from the pixels **540** comprising row **534**(**0**) may be referred to as an analog signal, and this analog signal may be based on an optical image focused on the pixel array **510**.

Further, after reading the pixels **540** comprising row **534**(**0**), the row logic **512** may select a second row of pixels **540** to be read. For example, the row logic **512** may assert one or more row select signals comprising row control signals **530**(*r*) associated with a row of pixels **540** that includes pixel **540**(*b*) and pixel **540**(*z*). As a result, the column read out circuit **520** may receive a corresponding set of analog values associated with pixels **540** comprising row **534**(*r*).

The column read out circuit **520** may serve as a multiplexer to select and forward one or more received analog values to an analog-to-digital converter circuit, such as analog-to-digital unit **622** of FIG. **6**. The column read out circuit **520** may forward the received analog values in a predefined order or sequence. In one embodiment, row logic **512** asserts one or more row selection signals comprising row control signals **530**, causing a corresponding row of pixels to transmit analog values through column signals **532**. The column read out circuit **520** receives the analog values and sequentially selects and forwards one or more of the analog values at a time to the analog-to-digital unit **622**. Selection of rows by row logic **512** and selection of columns by column read out circuit **620** may be directed by control unit **514**. In one embodiment, rows **534** are sequentially selected to be read, starting with row **534(0)** and ending with row **534**(*r*), and analog values associated with sequential columns are transmitted to the analog-to-digital unit **622**. In other embodiments, other selection patterns may be implemented to read analog values stored in pixels **540**.

Further, the analog values forwarded by the column read out circuit **520** may comprise analog pixel data, which may later be amplified and then converted to digital pixel data for generating one or more digital images based on an optical image focused on the pixel array **510**.

FIGS. **5**B-**5**D illustrate three optional pixel configurations, according to one or more embodiments. As an option, these pixel configurations may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, these pixel configurations may be implemented in any desired environment. By way of a specific example, any of the pixels **540** of FIGS. **5**B-**5**D may operate as one or more of the pixels **540** of the pixel array **510**.

As shown in FIG. **5**B, a pixel **540** is illustrated to include a first cell (R) for measuring red light intensity, second and third cells (G) for measuring green light intensity, and a fourth cell (B) for measuring blue light intensity, in accordance with one embodiment. As shown in FIG. **5**C, a pixel **540** is illustrated to include a first cell (R) for measuring red light intensity, a second cell (G) for measuring green light intensity, a third cell (B) for measuring blue light intensity, and a fourth cell (W) for measuring white light intensity, in accordance with another embodiment. As shown in FIG. **5**D, a pixel **540** is illustrated to include a first cell (C) for measuring cyan light intensity, a second cell (M) for measuring magenta light intensity, a third cell (Y) for measuring yellow light intensity, and a fourth cell (W) for measuring white light intensity, in accordance with yet another embodiment.

Of course, while pixels **540** are each shown to include four cells, a pixel **540** may be configured to include fewer or more cells for measuring light intensity. Still further, in another embodiment, while certain of the cells of pixel **540** are shown to be configured to measure a single peak wavelength of light, or white light, the cells of pixel **540** may be configured to measure any wavelength, range of wavelengths of light, or plurality of wavelengths of light.

Referring now to FIG. **5**E, a system is shown for capturing optical scene information focused as an optical image on an image sensor **332**, in accordance with one embodiment. As an option, the system of FIG. **5**E may be implemented in the context of the details of any of the Figures. Of course, however, the system of FIG. **5**E may be carried out in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

As shown in FIG. **5**E, an image sensor **332** is shown to include a first cell **544**, a second cell **545**, and a third cell **548**. Further, each of the cells **544-548** is shown to include a photodiode **562**. Still further, upon each of the photodiodes **562** is a corresponding filter **564**, and upon each of the filters **564** is a corresponding microlens **566**. For example, the cell **544** is shown to include photodiode **562(0)**, upon which is filter **564(0)**, and upon which is microlens **566(0)**. Similarly, the cell **545** is shown to include photodiode **562(1)**, upon which is filter **564(1)**, and upon which is microlens **566(1)**. Still yet, as shown in FIG. **5**E, pixel **540** is shown to include each of cells **544** and **545**, photodiodes **562(0)** and **562(1)**, filters **564(0)** and **564(1)**, and microlenses **566(0)** and **566(1)**.

In one embodiment, each of the microlenses **566** may be any lens with a diameter of less than 50 microns. However, in other embodiments each of the microlenses **566** may have a diameter greater than or equal to 50 microns. In one embodiment, each of the microlenses **566** may include a spherical convex surface for focusing and concentrating received light on a supporting substrate beneath the microlens **566**. For example, as shown in FIG. **5**E, the microlens **566(0)** focuses and concentrates received light on the filter **564(0)**. In one embodiment, a microlens array **567** may include microlenses **566**, each corresponding in placement to photodiodes **562** within cells **544** of image sensor **332**.

In the context of the present description, the photodiodes **562** may comprise any semiconductor diode that generates a potential difference, or changes its electrical resistance, in response to photon absorption. Accordingly, the photodiodes **562** may be used to detect or measure light intensity. Further, each of the filters **564** may be optical filters for selectively transmitting light of one or more predetermined wavelengths. For example, the filter **564(0)** may be configured to selectively transmit substantially only green light received from the corresponding microlens **566(0)**, and the filter **564(1)** may be configured to selectively transmit substantially only blue light received from the microlens **566(1)**. Together, the filters **564** and microlenses **566** may be operative to focus selected wavelengths of incident light on a plane. In one embodiment, the plane may be a 2-dimensional grid of photodiodes **562** on a surface of the image sensor **332**. Further, each photodiode **562** receives one or more predetermined wavelengths of light, depending on its associated filter. In one embodiment, each photodiode **562** receives only one of red, blue, or green wavelengths of filtered light. As shown with respect to FIGS. **5**B-**5**D, it is contemplated that a photodiode may be configured to detect wavelengths of light other than only red, green, or blue. For example, in the context of FIGS. **5**C-**5**D specifically, a photodiode may be configured to detect white, cyan, magenta, yellow, or non-visible light such as infrared or ultraviolet light.

To this end, each coupling of a cell, photodiode, filter, and microlens may be operative to receive light, focus and filter the received light to isolate one or more predetermined wavelengths of light, and then measure, detect, or otherwise quantify an intensity of light received at the one or more predetermined wavelengths. The measured or detected light may then be represented as an analog value stored within a cell. For example, in one embodiment, the analog value may be stored within the cell utilizing a capacitor, as discussed in more detail above. Further, the analog value stored within the cell may be output from the cell based on a selection signal, such as a row selection signal, which may be received from row logic **512**. Further still, the analog value transmitted from a single cell may comprise one analog value in a plurality of analog values of an analog signal, where each of the analog values is output by a different cell. Accordingly, the analog signal may comprise a plurality of analog pixel data values from a plurality of cells. In one embodiment, the analog signal may comprise analog pixel data values for an entire image of

a photographic scene. In another embodiment, the analog signal may comprise analog pixel data values for a subset of the entire image of the photographic scene. For example, the analog signal may comprise analog pixel data values for a row of pixels of the image of the photographic scene. In the context of FIGS. **5**A-**5**E, the row **534**(**0**) of the pixels **540** of the pixel array **510** may be one such row of pixels of the image of the photographic scene.

FIG. **6** illustrates a system for converting analog pixel data to digital pixel data, in accordance with an embodiment. As an option, the system of FIG. **6** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the system of FIG. **6** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

As shown in FIG. **6**, analog pixel data **621** is received from column read out circuit **520** at analog-to-digital unit **622** under the control of control unit **514**. The analog pixel data **621** may be received within an analog signal, as noted hereinabove. Further, the analog-to-digital unit **622** generates digital pixel data **625** based on the received analog pixel data **621**.

More specifically, and as shown in FIG. **6**, the analog-to-digital unit **622** includes an amplifier **650** and an analog-to-digital converter **654**. In one embodiment, the amplifier **650** receives both the analog pixel data **621** and a gain **652**, and applies the gain **652** to the analog pixel data **621** to generate gain-adjusted analog pixel data **623**. The gain-adjusted analog pixel data **623** is transmitted from the amplifier **650** to the analog-to-digital converter **654**. The analog-to-digital converter **654** receives the gain-adjusted analog pixel data **623**, and converts the gain-adjusted analog pixel data **623** to the digital pixel data **625**, which is then transmitted from the analog-to-digital converter **654**. In other embodiments, the amplifier **650** may be implemented within the column read out circuit **520** instead of within the analog-to-digital unit **622**. The analog-to-digital converter **654** may convert the gain-adjusted analog pixel data **623** to the digital pixel data **625** using any technically feasible analog-to-digital conversion system.

In an embodiment, the gain-adjusted analog pixel data **623** results from the application of the gain **652** to the analog pixel data **621**. In one embodiment, the gain **652** may be selected by the analog-to-digital unit **622**. In another embodiment, the gain **652** may be selected by the control unit **514**, and then supplied from the control unit **514** to the analog-to-digital unit **622** for application to the analog pixel data **621**.

It should be noted, in one embodiment, that a consequence of applying the gain **652** to the analog pixel data **621** is that analog noise may appear in the gain-adjusted analog pixel data **623**. If the amplifier **650** imparts a significantly large gain to the analog pixel data **621** in order to obtain highly sensitive data from of the pixel array **510**, then a significant amount of noise may be expected within the gain-adjusted analog pixel data **623**. In one embodiment, the detrimental effects of such noise may be reduced by capturing the optical scene information at a reduced overall exposure. In such an embodiment, the application of the gain **652** to the analog pixel data **621** may result in gain-adjusted analog pixel data with proper exposure and reduced noise.

In one embodiment, the amplifier **650** may be a transimpedance amplifier (TIA). Furthermore, the gain **652** may be specified by a digital value. In one embodiment, the digital value specifying the gain **652** may be set by a user of a digital photographic device, such as by operating the digital photographic device in a "manual" mode. Still yet, the digital value may be set by hardware or software of a digital photographic device. As an option, the digital value may be set by the user working in concert with the software of the digital photographic device.

In one embodiment, a digital value used to specify the gain **652** may be associated with an ISO. In the field of photography, the ISO system is a well-established standard for specifying light sensitivity. In one embodiment, the amplifier **650** receives a digital value specifying the gain **652** to be applied to the analog pixel data **621**. In another embodiment, there may be a mapping from conventional ISO values to digital gain values that may be provided as the gain **652** to the amplifier **650**. For example, each of ISO 100, ISO 200, ISO 400, ISO 800, ISO 1600, etc. may be uniquely mapped to a different digital gain value, and a selection of a particular ISO results in the mapped digital gain value being provided to the amplifier **650** for application as the gain **652**. In one embodiment, one or more ISO values may be mapped to a gain of 1. Of course, in other embodiments, one or more ISO values may be mapped to any other gain value.

Accordingly, in one embodiment, each analog pixel value may be adjusted in brightness given a particular ISO value. Thus, in such an embodiment, the gain-adjusted analog pixel data **623** may include brightness corrected pixel data, where the brightness is corrected based on a specified ISO. In another embodiment, the gain-adjusted analog pixel data **623** for an image may include pixels having a brightness in the image as if the image had been sampled at a certain ISO.

In accordance with an embodiment, the digital pixel data **625** may comprise a plurality of digital values representing pixels of an image captured using the pixel array **510**.

FIG. **7** illustrates a system **700** for converting analog pixel data of an analog signal to digital pixel data, in accordance with an embodiment. As an option, the system **700** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the system **700** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

The system **700** is shown in FIG. **7** to include an analog storage plane **702**, an analog-to-digital unit **722**, a first digital image **732**, and a second digital image **734**. Additionally, in one embodiment, analog values may each be depicted as a "V" within the analog storage plane **702** and corresponding digital values may each be depicted as a "D" within first digital image **732** and second digital image **734**.

In the context of the present description, the analog storage plane **702** may comprise any collection of one or more analog values. In one embodiment, the analog storage plane **702** may comprise one or more analog pixel values. In some embodiments, the analog storage plane **702** may comprise at least one analog pixel value for each pixel of a row or line of a pixel array. Still yet, in another embodiment, the analog storage plane **702** may comprise at least one analog pixel value for each pixel of an entirety of a pixel array, which may be referred to as a frame. In one embodiment, the analog storage plane **702** may comprise an analog value for each cell of a pixel. In yet another embodiment, the analog storage plane **702** may comprise an analog value for each cell of each pixel of a row or line of a pixel array. In another embodiment, the analog storage plane **702** may comprise an analog value for each cell of each pixel of multiple lines or rows of a pixel array. For example, the analog storage plane **702** may comprise an analog value for each cell of each pixel of every line or row of a pixel array.

Further, the analog values of the analog storage plane **702** are output as analog pixel data **704** to the analog-to-digital unit **722**. In one embodiment, the analog-to-digital unit **722**

may be substantially identical to the analog-to-digital unit **622** described within the context of FIG. **6**. For example, the analog-to-digital unit **722** may comprise at least one amplifier and at least one analog-to-digital converter, where the amplifier is operative to receive a gain value and utilize the gain value to gain-adjust analog pixel data received at the analog-to-digital unit **722**. Further, in such an embodiment, the amplifier may transmit gain-adjusted analog pixel data to an analog-to-digital converter, which then generates digital pixel data from the gain-adjusted analog pixel data.

In the context of the system **700** of FIG. **7**, the analog-to-digital unit **722** receives the analog pixel data **704**, and applies at least two different gains to the analog pixel data **704** to generate at least a first gain-adjusted analog pixel data and a second gain-adjusted analog pixel data. Further, the analog-to-digital unit **722** converts each generated gain-adjusted analog pixel data to digital pixel data, and then outputs at least two digital outputs. To this end, the analog-to-digital unit **722** provides a different digital output corresponding to each gain applied to the analog pixel data **704**. With respect to FIG. **7** specifically, the analog-to-digital unit **722** is shown to generate a first digital signal comprising first digital pixel data **723** corresponding to a first gain **652**, and a second digital signal comprising second digital pixel data **724** corresponding to a second gain **752**.

In one embodiment, the analog-to-digital unit **722** applies in sequence the at least two gains to the analog values. For example, the analog-to-digital unit **722** first applies the first gain **652** to the analog pixel data **704**, and then subsequently applies the second gain **752** to the same analog pixel data **704**. In other embodiments, the analog-to-digital unit **722** may apply in parallel the at least two gains to the analog values. For example, the analog-to-digital unit **722** may apply the first gain **652** to the analog pixel data **704** in parallel with the application of the second gain **752** to the analog pixel data **704**. To this end, as a result of applying the at least two gains, the analog pixel data **704** is amplified utilizing at least the first gain **652** and the second gain **752**.

In accordance with one embodiment, the at least two gains may be determined using any technically feasible technique based on an exposure of a photographic scene, metering data, user input, detected ambient light, a strobe control, or any combination of the foregoing. For example, a first gain of the at least two gains may be determined such that half of the digital values from the analog storage plane **702** are converted to digital values above a specified threshold (e.g., a threshold of 0.5 in a range of 0.0 to 1.0) for the dynamic range associated with digital values comprising the first digital image **732**, which can be characterized as having an "EV0" exposure. Continuing the example, a second gain of the at least two gains may be determined as being twice that of the first gain to generate a second digital image **734** characterized as having an "EV+1" exposure.

In one embodiment, the analog-to-digital unit **722** converts in sequence the first gain-adjusted analog pixel data to the first digital pixel data **723**, and the second gain-adjusted analog pixel data to the second digital pixel data **724**. For example, the analog-to-digital unit **722** first converts the first gain-adjusted analog pixel data to the first digital pixel data **723**, and then subsequently converts the second gain-adjusted analog pixel data to the second digital pixel data **724**. In other embodiments, the analog-to-digital unit **722** may perform such conversions in parallel, such that the first digital pixel data **723** is generated in parallel with the second digital pixel data **724**.

Still further, as shown in FIG. **7**, the first digital pixel data **723** is used to provide the first digital image **732**. Similarly, the second digital pixel data **724** is used to provide the second digital image **734**. The first digital image **732** and the second digital image **734** are both based upon the same analog pixel data **704**, however the first digital image **732** may differ from the second digital image **734** as a function of a difference between the first gain **652** (used to generate the first digital image **732**) and the second gain **752** (used to generate the second digital image **752**). Specifically, the digital image generated using the largest gain of the at least two gains may be visually perceived as the brightest or more exposed. Conversely, the digital image generated using the smallest gain of the at least two gains may be visually perceived as the darkest and less exposed. To this end, a first light sensitivity value may be associated with the first digital pixel data **723**, and a second light sensitivity value may be associated with the second digital pixel data **724**. Further, because each of the gains may be associated with a different light sensitivity value, the first digital image or first digital signal may be associated with a first light sensitivity value, and the second digital image or second digital signal may be associated with a second light sensitivity value.

It should be noted that while a controlled application of gain to the analog pixel data may greatly aid in HDR image generation, an application of too great of gain may result in a digital image that is visually perceived as being noisy, over-exposed, and/or blown-out. In one embodiment, application of two stops of gain to the analog pixel data may impart visually perceptible noise for darker portions of a photographic scene, and visually imperceptible noise for brighter portions of the photographic scene. In another embodiment, a digital photographic device may be configured to provide an analog storage plane of analog pixel data for a captured photographic scene, and then perform at least two analog-to-digital samplings of the same analog pixel data using the analog-to-digital unit **722**. To this end, a digital image may be generated for each sampling of the at least two samplings, where each digital image is obtained at a different exposure despite all the digital images being generated from the same analog sampling of a single optical image focused on an image sensor.

In one embodiment, an initial exposure parameter may be selected by a user or by a metering algorithm of a digital photographic device. The initial exposure parameter may be selected based on user input or software selecting particular capture variables. Such capture variables may include, for example, ISO, aperture, and shutter speed. An image sensor may then capture a single exposure of a photographic scene at the initial exposure parameter, and populate an analog storage plane with analog values corresponding to an optical image focused on the image sensor. Next, a first digital image may be obtained utilizing a first gain in accordance with the above systems and methods. For example, if the digital photographic device is configured such that the initial exposure parameter includes a selection of ISO 400, the first gain utilized to obtain the first digital image may be mapped to, or otherwise associated with, ISO 400. This first digital image may be referred to as an exposure or image obtained at exposure value 0 (EV0). Further at least one more digital image may be obtained utilizing a second gain in accordance with the above systems and methods. For example, the same analog pixel data used to generate the first digital image may be processed utilizing a second gain to generate a second digital image.

In one embodiment, at least two digital images may be generated using the same analog pixel data and blended to generate an HDR image. The at least two digital images generated using the same analog signal may be blended by

blending a first digital signal and a second digital signal. Because the at least two digital images are generated using the same analog pixel data, there may be zero interframe time between the at least two digital images. As a result of having zero interframe time between at least two digital images of a same photographic scene, an HDR image may be generated without motion blur or other artifacts typical of HDR photographs.

In another embodiment, the second gain may be selected based on the first gain. For example, the second gain may be selected on the basis of it being one stop away from the first gain. More specifically, if the first gain is mapped to or associated with ISO 400, then one stop down from ISO 400 provides a gain associated with ISO 200, and one stop up from ISO 400 provides a gain associated with ISO 800. In such an embodiment, a digital image generated utilizing the gain associated with ISO 200 may be referred to as an exposure or image obtained at exposure value −1 (EV−1), and a digital image generated utilizing the gain associated with ISO 800 may be referred to as an exposure or image obtained at exposure value +1 (EV+1).

Still further, if a more significant difference in exposures is desired between digital images generated utilizing the same analog signal, then the second gain may be selected on the basis of it being two stops away from the first gain. For example, if the first gain is mapped to or associated with ISO 400, then two stops down from ISO 400 provides a gain associated with ISO 100, and two stops up from ISO 400 provides a gain associated with ISO 1600. In such an embodiment, a digital image generated utilizing the gain associated with ISO 100 may be referred to as an exposure or image obtained at exposure value −2 (EV−2), and a digital image generated utilizing the gain associated with ISO 1600 may be referred to as an exposure or image obtained at exposure value +2 (EV+2).

In one embodiment, an ISO and exposure of the EV0 image may be selected according to a preference to generate darker or more saturated digital images. In such an embodiment, the intention may be to avoid blowing out or overexposing what will be the brightest digital image, which is the digital image generated utilizing the greatest gain. In another embodiment, an EV−1 digital image or EV−2 digital image may be a first generated digital image. Subsequent to generating the EV−1 or EV−2 digital image, an increase in gain at an analog-to-digital unit may be utilized to generate an EV0 digital image, and then a second increase in gain at the analog-to-digital unit may be utilized to generate an EV+1 or EV+2 digital image. In one embodiment, the initial exposure parameter corresponds to an EV−N digital image and subsequent gains are used to obtain an EV0 digital image, an EV+M digital image, or any combination thereof, where N and M are values ranging from 0 to −10.

In one embodiment, an EV−2 digital image, an EV0 digital image, and an EV+2 digital image may be generated in parallel by implementing three analog-to-digital units. Such an implementation may be also capable of simultaneously generating all of an EV−1 digital image, an EV0 digital image, and an EV+1 digital image. Similarly, any combination of exposures may be generated in parallel from two or more analog-to-digital units, three or more analog-to-digital units, or an arbitrary number of analog-to-digital units.

FIG. **8** illustrates various timing configurations for amplifying analog signals, in accordance with various embodiments. As an option, the timing configurations of FIG. **8** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the timing configurations of FIG. **8** may be carried out in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

Specifically, as shown in FIG. **8**, per pixel timing configuration **801** is shown to amplify analog signals on a pixel-by-pixel basis. Further, per line timing configuration **811** is shown to amplify analog signals on a line-by-line basis. Finally, per frame timing configuration **821** is shown to amplify analog signals on a frame-by-frame basis. Each amplified analog signal associated with analog pixel data may be converted to a corresponding digital signal value.

In systems that implement per pixel timing configuration **801**, an analog signal containing analog pixel data may be received at an analog-to-digital unit. Further, the analog pixel data may include individual analog pixel values. In such an embodiment, a first analog pixel value associated with a first pixel may be identified within the analog signal and selected. Next, each of a first gain **803**, a second gain **805**, and a third gain **807** may be applied in sequence or concurrently to the same first analog pixel value. In some embodiments less than or more than three different gains may be applied to a selected analog pixel value. For example, in some embodiments applying only two different gains to the same analog pixel value may be sufficient for generating a satisfactory HDR image. In one embodiment, after applying each of the first gain **803**, the second gain **805**, and the third gain **807**, a second analog pixel value associated with a second pixel may be identified within the analog signal and selected. The second pixel may be a neighboring pixel of the first pixel. For example, the second pixel may be in a same row as the first pixel and located adjacent to the first pixel on a pixel array of an image sensor. Next, each of the first gain **803**, the second gain **805**, and the third gain **807** may be applied in sequence or concurrently to the same second analog pixel value. To this end, in the per pixel timing configuration **801**, a plurality of sequential analog pixel values may be identified within an analog signal, and a set of at least two gains are applied to each pixel in the analog signal on a pixel-by-pixel basis.

Further, in systems that implement the per pixel timing configuration **801**, a control unit may select a next gain to be applied after each pixel is amplified using a previously selected gain. In another embodiment, a control unit may control an amplifier to cycle through a set of predetermined gains that will be applied to a first analog pixel value, such a first analog pixel data value comprising analog pixel data **704**, associated with a first pixel so that each gain in the set may be used to amplify the first analog pixel data before applying the set of predetermined gains to a second analog pixel data that subsequently arrives at the amplifier. In one embodiment, and as shown in the context of FIG. **8**, this may include selecting a first gain, applying the first gain to a received first analog pixel value, selecting a second gain, applying the second gain to the received first analog pixel value, selecting a third gain, applying the third selected gain to the received first analog pixel value, and then receiving a second analog pixel value and applying the three selected gains to the second pixel value in the same order as applied to the first pixel value. In one embodiment, each analog pixel value may be read a plurality of times. In general, an analog storage plane may be utilized to hold the analog pixel values of the pixels for reading.

In systems that implement per line timing configuration **811**, an analog signal containing analog pixel data may be received at an analog-to-digital unit. Further, the analog pixel data may include individual analog pixel values. In one embodiment, a first line of analog pixel values associated with a first line of pixels of a pixel array may be identified within the analog signal and selected. Next, each of a first gain **813**, a second gain **815**, and a third gain **817** may be applied in

sequence or concurrently to the same first line of analog pixel values. In some embodiments less than or more than three different gains may be applied to a selected line of analog pixel values. For example, in some embodiments applying only two different gains to the same line of analog pixel values may be sufficient for generating a satisfactory HDR image. In one embodiment, after applying each of the first gain **813**, the second gain **815**, and the third gain **817**, a second line of analog pixel values associated with a second line of pixels may be identified within the analog signal and selected. The second line of pixels may be a neighboring line of the first line of pixels. For example, the second line of pixels may be located immediately above or immediately below the first line of pixels in a pixel array of an image sensor. Next, each of the first gain **813**, the second gain **815**, and the third gain **817** may be applied in sequence or concurrently to the same second line of analog pixel values. To this end, in the per line timing configuration **811**, a plurality of sequential lines of analog pixel values are identified within an analog signal, and a set of at least two gains are applied to each line of analog pixel values in the analog signal on a line-by-line basis.

Further, in systems that implement the per line timing configuration **811**, a control unit may select a next gain to be applied after each line is amplified using a previously selected gain. In another embodiment, a control unit may control an amplifier to cycle through a set of predetermined gains that will be applied to a line so that each gain in the set is used to amplify a first line of analog pixel values before applying the set of predetermined gains to a second line of analog pixel values that arrives at the amplifier subsequent to the first line of analog pixel values. In one embodiment, and as shown in the context of FIG. **8**, this may include selecting a first gain, applying the first gain to a received first line of analog pixel values, selecting a second gain, applying the second gain to the received first line of analog pixel values, selecting a third gain, applying the third selected gain to the received first line of analog pixel values, and then receiving a second line of analog pixel values and applying the three selected gains to the second line of analog pixel values in the same order as applied to the first line of analog pixel values. In one embodiment, each line of analog pixel values may be read a plurality of times. In another embodiment, an analog storage plane may be utilized to hold the analog pixel data values of one or more lines for reading.

In systems that implement per frame timing configuration **821**, an analog signal that contains a plurality of analog pixel data values comprising analog pixel values may be received at an analog-to-digital unit. In such an embodiment, a first frame of analog pixel values associated with a first frame of pixels may be identified within the analog signal and selected. Next, each of a first gain **823**, a second gain **825**, and a third gain **827** may be applied in sequence or concurrently to the same first frame of analog pixel values. In some embodiments less than or more than three different gains may be applied to a selected frame of analog pixel values. For example, in some embodiments applying only two different gains to the same frame of analog pixel values may be sufficient for generating a satisfactory HDR image.

In one embodiment, after applying each of the first gain **823**, the second gain **825**, and the third gain **827**, a second frame of analog pixel values associated with a second frame of pixels may be identified within the analog signal and selected. The second frame of pixels may be a next frame in a sequence of frames that capture video data associated with a photographic scene. For example, a digital photographic system may be operative to capture 30 frames per second of video data. In such digital photographic systems, the first frame of pixels may be one frame of said thirty frames, and the second frame of pixels may be a second frame of said thirty frames. Further still, each of the first gain **823**, the second gain **825**, and the third gain **827** may be applied in sequence to the analog pixel values of the second frame. To this end, in the per frame timing configuration **821**, a plurality of sequential frames of analog pixel values may be identified within an analog signal, and a set of at least two gains are applied to each frame of analog pixel values on a frame-by-frame basis.

Further, in systems that implement the per frame timing configuration **821**, a control unit may select a next gain to be applied after each frame is amplified using a previously selected gain. In another embodiment, a control unit may control an amplifier to cycle through a set of predetermined gains that will be applied to a frame so that each gain is used to amplify a analog pixel values associated with the first frame before applying the set of predetermined gains to analog pixel values associated with a second frame that subsequently arrive at the amplifier. In one embodiment, and as shown in the context of FIG. **8**, this may include selecting a first gain, applying the first gain to analog pixel values associated with the first frame, selecting a second gain, applying the second gain to analog pixel values associated with the first frame, selecting a third gain, and applying the third gain to analog pixel values associated with the first frame. In another embodiment, analog pixel values associated with a second frame may be received following the application of all three selected gains to analog pixel values associated with the first frame, and the three selected gains may then be applied to analog pixel values associated with the second frame in the same order as applied to the first frame.

In yet another embodiment, selected gains applied to the first frame may be different than selected gains applied to the second frame, such as may be the case when the second frame includes different content and illumination than the first frame. In general, an analog storage plane may be utilized to hold the analog pixel data values of one or more frames for reading.

FIG. **9** illustrates a system **900** for converting in parallel analog pixel data to multiple signals of digital pixel data, in accordance with one embodiment. As an option, the system **900** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the system **900** may be implemented in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In the context of FIG. **9**, the system **900** is shown to receive as input analog pixel data **621**. The analog pixel data **621** may be received within an analog signal, as noted hereinabove. Further, the analog-to-digital units **622** may be configured to generate digital pixel data **625** based on the received analog pixel data **621**.

As shown in FIG. **9**, the system **900** is configured to mirror the current of the analog pixel data **621** such that each of analog-to-digital unit **622(0)**, analog-to-digital unit **622(1)**, and analog-to-digital unit **622(*n*)** receive a scaled copy of the analog pixel data **621**. In one embodiment, each of the analog-to-digital unit **622(0)**, the analog-to-digital unit **622(1)**, and the analog-to-digital unit **622(*n*)** may be configured to apply a unique gain to the analog pixel data **621**. Each scaled copy may be scaled according to physical dimensions for the transistors comprising system **900**, which comprises a structure known in the art as a current mirror. As shown, each current **i1**, **i2**, **i3** may be generated in an arbitrary ratio relative to input current Iin, based on the physical dimensions. For example,

currents i1, i2, i3 may be generated in a ratio of 1:1:1, 1:2:4, 0.5:1:2, or any other technically feasible ratio relative to Iin.

In an embodiment, the unique gains may be configured at each of the analog-to-digital units **622** by a controller. By way of a specific example, the analog-to-digital unit **622**(**0**) may be configured to apply a gain of 1.0 to the analog pixel data **621**, the analog-to-digital unit **622**(**1**) may be configured to apply a gain of 2.0 to the analog pixel data **621**, and the analog-to-digital unit **622**(*n*) may be configured to apply a gain of 4.0 to the analog pixel data **621**. Accordingly, while the same analog pixel data **621** may be input transmitted to each of the analog-to-digital unit **622**(**0**), the analog-to-digital unit **622**(**1**), and the analog-to-digital unit **622**(*n*), each of digital pixel data **625**(**0**), digital pixel data **625**(**1**), and digital pixel data **625**(*n*) may include different digital values based on the different gains applied within the analog-to-digital units **622**, and thereby provide unique exposure representations of the same photographic scene.

In the embodiment described above, where the analog-to-digital unit **622**(**0**) may be configured to apply a gain of 1.0, the analog-to-digital unit **622**(**1**) may be configured to apply a gain of 2.0, and the analog-to-digital unit **622**(*n*) may be configured to apply a gain of 4.0, the digital pixel data **625**(**0**) may provide the least exposed corresponding digital image. Conversely, the digital pixel data **625**(*n*) may provide the most exposed digital image. In another embodiment, the digital pixel data **625**(**0**) may be utilized for generating an EV−1 digital image, the digital pixel data **625**(**1**) may be utilized for generating an EV0 digital image, and the digital pixel data **625**(*n*) may be utilized for generating an EV+2 image. In another embodiment, system **900** is configured to generate currents i1, i2, and i3 in a ratio of 2:1:4, and each analog-to-digital unit **622** may be configured to apply a gain of 1.0, which results in corresponding digital images having exposure values of EV−1, EV0, and EV+1 respectively. In such an embodiment, further differences in exposure value may be achieved by applying non-unit gain within one or more analog-to-digital unit **622**.

While the system **900** is illustrated to include three analog-to-digital units **622**, it is contemplated that multiple digital images may be generated by similar systems with more or less than three analog-to-digital units **622**. For example, a system with two analog-to-digital units **622** may be implemented for simultaneously generating two exposures of a photographic scene with zero interframe time in a manner similar to that described above with respect to system **900**. In one embodiment, the two analog-to-digital units **622** may be configured to generate two exposures each, for a total of four different exposures relative to one frame of analog pixel data.

FIG. **10** illustrates a user interface (UI) system **1000** for generating a combined image **1020**, according to one embodiment. As an option, the UI system **1000** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the UI system **1000** may be carried out in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

In one embodiment, a combined image **1020** comprises a combination of at least two related digital images. In one embodiment, the combined image **1020** comprises, without limitation, a combined rendering of a first digital image and a second digital image, such first digital image **732** and second digital image **734** of FIG. **7**. In another embodiment, the digital images used to compute the combined image **1020** may be generated by amplifying an analog signal with at least two different gains, where the analog signal includes optical scene information captured based on an optical image focused on an image sensor. In yet another embodiment, the analog signal may be amplified using the at least two different gains on a pixel-by-pixel, line-by-line, or frame-by-frame basis.

In one embodiment, the UI system **1000** presents a display image **1010** that includes, without limitation, a combined image **1020**, a slider control **1030** configured to move along track **1032**, and two or more indication points **1040**, which may each include a visual marker displayed within display image **1010**.

In one embodiment, the UI system **1000** is generated by an adjustment tool executing within a processor complex **310** of a digital photographic system **300**, and the display image **1010** is displayed on display unit **312**. In one embodiment, at least two digital images, such as the at least two related digital images, comprise source images for generating the combined image **1020**. The at least two digital images may reside within NV memory **316**, volatile memory **318**, memory subsystem **362**, or any combination thereof. In another embodiment, the UI system **1000** is generated by an adjustment tool executing within a computer system, such as a laptop computer or a desktop computer. The at least two digital images may be transmitted to the computer system or may be generated by an attached camera device. In yet another embodiment, the UI system **1000** may be generated by a cloud-based server computer system, which may download the at least two digital images to a client browser, which may execute combining operations described below. In another embodiment, the UI system **1000** is generated by a cloud-based server computer system, which receives the at least two digital images from a digital photographic system in a mobile device, and which may execute the combining operations described below in conjunction with generating combined image **1020**.

The slider control **1030** may be configured to move between two end points corresponding to indication points **1040**-A and **1040**-C. One or more indication points, such as indication point **1040**-B may be positioned between the two end points. Each indication point **1040** may be associated with a specific version of combined image **1020**, or a specific combination of the at least two digital images. For example, the indication point **1040**-A may be associated with a first digital image generated utilizing a first gain, and the indication point **1040**-C may be associated with a second digital image generated utilizing a second gain, where both of the first digital image and the second digital image are generated from a same analog signal of a single captured photographic scene. In one embodiment, when the slider control **1030** is positioned directly over the indication point **1040**-A, only the first digital image may be displayed as the combined image **1020** in the display image **1010**, and similarly when the slider control **1030** is positioned directly over the indication point **1040**-C, only the second digital image may be displayed as the combined image **1020** in the display image **1010**.

In one embodiment, indication point **1040**-B may be associated with a blending of the first digital image and the second digital image. For example, when the slider control **1030** is positioned at the indication point **1040**-B, the combined image **1020** may be a blend of the first digital image and the second digital image. In one embodiment, blending of the first digital image and the second digital image may comprise alpha blending, brightness blending, dynamic range blending, and/or tone mapping or other non-linear blending and mapping operations. In another embodiment, any blending of the first digital image and the second digital image may provide a new image that has a greater dynamic range or other visual characteristics that are different than either of the first image and the second image alone. Thus, a blending of the

first digital image and the second digital image may provide a new computed HDR image that may be displayed as combined image **1020** or used to generate combined image **1020**. To this end, a first digital signal and a second digital signal may be combined, resulting in at least a portion of a HDR image. Further, one of the first digital signal and the second digital signal may be further combined with at least a portion of another digital image or digital signal. In one embodiment, the other digital image may include another HDR image.

In one embodiment, when the slider control **1030** is positioned at the indication point **1040**-A, the first digital image is displayed as the combined image **1020**, and when the slider control **1030** is positioned at the indication point **1040**-C, the second digital image is displayed as the combined image **1020**; furthermore, when slider control **1030** is positioned at indication point **1040**-B, a blended image is displayed as the combined image **1020**. In such an embodiment, when the slider control **1030** is positioned between the indication point **1040**-A and the indication point **1040**-C, a mix (e.g. blend) weight may be calculated for the first digital image and the second digital image. For the first digital image, the mix weight may be calculated as having a value of 0.0 when the slider control **1030** is at indication point **1040**-C and a value of 1.0 when slider control **1030** is at indication point **1040**-A, with a range of mix weight values between 0.0 and 1.0 located between the indication points **1040**-C and **1040**-A, respectively. Referencing the mix operation instead to the second digital image, the mix weight may be calculated as having a value of 0.0 when the slider control **1030** is at indication point **1040**-A and a value of 1.0 when slider control **1030** is at indication point **1040**-C, with a range of mix weight values between 0.0 and 1.0 located between the indication points **1040**-A and **1040**-C, respectively.

A mix operation may be applied to the first digital image and the second digital image based upon at least one mix weight value associated with at least one of the first digital image and the second digital image. In one embodiment, a mix weight of 1.0 gives complete mix weight to the digital image associated with the 1.0 mix weight. In this way, a user may blend between the first digital image and the second digital image. To this end, a first digital signal and a second digital signal may be blended in response to user input. For example, sliding indicia may be displayed, and a first digital signal and a second digital signal may be blended in response to the sliding indicia being manipulated by a user.

This system of mix weights and mix operations provides a UI tool for viewing the first digital image, the second digital image, and a blended image as a gradual progression from the first digital image to the second digital image. In one embodiment, a user may save a combined image **1020** corresponding to an arbitrary position of the slider control **1030**. The adjustment tool implementing the UI system **1000** may receive a command to save the combined image **1020** via any technically feasible gesture or technique. For example, the adjustment tool may be configured to save the combined image **1020** when a user gestures within the area occupied by combined image **1020**. Alternatively, the adjustment tool may save the combined image **1020** when a user presses, but does not otherwise move the slider control **1030**. In another implementation, the adjustment tool may save the combined image **1020** when a user gestures, such as by pressing a UI element (not shown), such as a save button, dedicated to receive a save command.

To this end, a slider control may be used to determine a contribution of two or more digital images to generate a final computed image, such as combined image **1020**. Persons skilled in the art will recognize that the above system of mix weights and mix operations may be generalized to include two or more indication points, associated with two or more related images. Such related images may comprise, without limitation, any number of digital images that have been generated using a same analog signal to have different brightness values, which may have zero interframe time.

Furthermore, a different continuous position UI control, such as a rotating knob, may be implemented rather than the slider control **1030** to provide mix weight input or color adjustment input from the user.

FIG. **11** is a flow diagram of method **1100** for generating a combined image, according to one embodiment. As an option, the method **1100** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the method **1100** may be carried out in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

The method **1100** begins in step **1110**, where an adjustment tool executing within a processor complex, such as processor complex **310**, loads at least two related source images, such as the first digital image and the second digital image described in the context of FIG. **10**. In step **1112**, the adjustment tool initializes a position for a UI control, such as slider control **1030** of FIG. **10**, to a default setting. In one embodiment, the default setting comprises an end point, such as indication point **1040**-A, for a range of values for the UI control. In another embodiment, the default setting comprises a calculated value based on one or more of the at least two related source images. In certain embodiments, the default setting is initialized to a value previously selected by a user in association with an image object comprising at least the first digital image and the second digital image.

In step **1114**, the adjustment tool generates and displays a combined image, such as combined image **1020** of FIG. **10**, based on a position of the UI control and the at least two related source images. In one embodiment, generating the combined image comprises mixing the at least two related source images as described previously in FIG. **10**. In step **1116**, the adjustment tool receives user input. The user input may include, without limitation, a UI gesture such as a selection gesture or click gesture within display image **1010**. If, in step **1120**, the user input should change the position of the UI control, then the adjustment tool changes the position of the UI control and the method proceeds back to step **1114**. Otherwise, the method proceeds to step **1130**.

If, in step **1130**, the user input does not comprise a command to exit, then the method proceeds to step **1140**, where the adjustment tool performs a command associated with the user input. In one embodiment, the command comprises a save command and the adjustment tool then saves the combined image, which is generated according to a position of the UI control. The method then proceeds back to step **1116**.

Returning to step **1130**, if the user input comprises a command to exit, then the method terminates in step **1190**, where the adjustment tool exits, thereby terminating execution.

In summary, a technique is disclosed for generating a new digital photograph that beneficially blends a first digital image and a second digital image, where the first digital image and the second digital image are both based on a single analog signal received from an image sensor. The first digital image may be blended with the second digital image based on a function that implements any technically feasible blend technique. An adjustment tool may implement a user interface technique that enables a user to select and save the new digital photograph from a gradation of parameters for combining related images.

One advantage of the present invention is that a digital photograph may be selectively generated based on user input using two or more different exposures of a single capture of a photographic scene. Accordingly, the digital photograph generated based on the user input may have a greater dynamic range than any of the individual exposures. Further, the generation of an HDR image using two or more different exposures with zero interframe time allows for the rapid generation of HDR images without motion artifacts.

FIG. **12** illustrates a message sequence **1200** for generating a combined image utilizing a network, according to one embodiment. As an option, the message sequence **1200** may be implemented in the context of the details of any of the Figures disclosed herein. Of course, however, the message sequence **1200** may be carried out in any desired environment. Further, the aforementioned definitions may equally apply to the description below.

As shown in FIG. **12**, a wireless mobile device **376**(**0**) generates at least two digital images. In one embodiment, the at least two digital images may be generated by amplifying an analog signal with at least two gains, where each generated digital image corresponds to digital output of an applied gain. As described previously, at least two different gains may be applied by one or more amplifiers to an analog signal containing analog pixel data in order to generate gain-adjusted analog pixel data. Further, the gain-adjusted analog pixel data may then be converted to the at least two digital images utilizing at least one analog-to-digital converter, where each of the digital images provides a different exposure of a same photographic scene. For example, in one embodiment, the at least two digital images may include an EV−1 exposure of the photographic scene and an EV+1 exposure of the photographic scene. In another embodiment, the at least two digital images may include an EV−2 exposure of the photographic scene, an EV0 exposure of the photographic scene, and an EV+2 exposure of the photographic scene.

Referring again to FIG. **12**, the at least two digital images are transmitted from the wireless mobile device **376**(**0**) to a data center **480** by way of a data network **474**. The at least two digital images may be transmitted by the wireless mobile device **376**(**0**) to the data center **480** using any technically feasible network communication method.

Further, in one embodiment, the data center **480** may then process the at least two digital images to generate a first computed image. The processing of the at least two digital images may include any processing of the at least two digital images that blends or merges at least a portion of each of the at least two digital images to generate the first computed image. To this end, the first digital image and the second digital image may be combined remotely from the wireless mobile device **376**(**0**). For example, the processing of the at least two digital images may include an any type of blending operation, including but not limited to, an HDR image combining operation. In one embodiment, the processing of the at least two digital images may include any computations that produce a first computed image having a greater dynamic range than any one of the digital images received at the data center **480**. Accordingly, in one embodiment, the first computed image generated by the data center **480** may be an HDR image. In other embodiments, the first computed image generated by the data center **480** may be at least a portion of an HDR image.

After generating the first computed image, the data center **480** may then transmit the first computed image to the wireless mobile device **376**(**0**). In one embodiment, the transmission of the at least two digital images from the wireless mobile device **376**(**0**), and the receipt of the first computed image at the wireless device **376**(**0**), may occur without any intervention or instruction being received from a user of the wireless mobile device **376**(**0**). For example, in one embodiment, the wireless mobile device **376**(**0**) may transmit the at least two digital images to the data center **480** immediately after capturing a photographic scene and generating the at least two digital images utilizing an analog signal representative of the photographic scene. The photographic scene may be captured based on a user input or selection of an electronic shutter control, or pressing of a manual shutter button, on the wireless mobile device **376**(**0**). Further, in response to receiving the at least two digital images, the data center **480** may generate an HDR image based on the at least two digital images, and transmit the HDR image to the wireless mobile device **376**(**0**). The wireless mobile device **376**(**0**) may then display the received HDR image. Accordingly, a user of the wireless mobile device **376**(**0**) may view on the display of the wireless mobile device **376**(**0**) an HDR image computed by the data center **480**. Thus, even though the wireless mobile device **376**(**0**) does not perform any HDR image processing, the user may view on the wireless mobile device **376**(**0**) the newly computed HDR image substantially instantaneously after capturing the photographic scene and generating the at least two digital images on which the HDR image is based.

As shown in FIG. **12**, the wireless mobile device **376**(**0**) requests adjustment in processing of the at least two digital images. In one embodiment, upon receiving the first computed image from the data center **480**, the wireless mobile device **376**(**0**) may display the first computed image in a UI system, such as the UI system **1000** of FIG. **10**. In such an embodiment, the user may control a slider control, such as the slider control **1030**, to adjust the processing of the at least two digital images transmitted to the data center **480**. For example, user manipulation of a slider control may result in commands being transmitted to the data center **480**. In one embodiment, the commands transmitted to the data center **480** may include mix weights for use in adjusting the processing of the at least two digital images. In other embodiments, the request to adjust processing of the at least two digital images includes any instructions from the wireless mobile device **376**(**0**) that the data center **480** may use to again process the at least two digital images and generate a second computed image.

As shown in FIG. **12**, upon receiving the request to adjust processing, the data center **480** re-processes the at least two digital images to generate a second computed image. In one embodiment, the data center **480** may re-process the at least two digital images using parameters received from the wireless mobile device **376**(**0**). In such an embodiment, the parameters may be provided as input with the at least two digital images to an HDR processing algorithm that executes at the data center **480**. After generating the second computed image, the second computed image may be then transmitted from the data center **480** to the wireless mobile device **376**(**0**) for display to the user.

Referring again to FIG. **12**, the wireless mobile device **376**(**0**) shares the second computed image with another wireless mobile device **376**(**1**). In one embodiment, the wireless mobile device **376**(**0**) may share any computed image received from the data center **480** with the other wireless mobile device **376**(**1**). For example, the wireless mobile device **376**(**0**) may share the first computed image received from the data center **480**. As shown in FIG. **12**, the data center **480** communicates with the wireless mobile device **376**(**0**) and the wireless mobile device **376**(**1**) over the same data network **474**. Of course, in other embodiments the wireless mobile device **376**(**0**) may communicate with the data center

480 via a network different than a network utilized by the data center 480 and the wireless mobile device 376(1) for communication.

In another embodiment, the wireless mobile device 376(0) may share a computed image with the other wireless mobile device 376(1) by transmitting a sharing request to data center 480. For example, the wireless mobile device 376(0) may request that the data center 480 forward the second computed to the other wireless mobile device 376(1). In response to receiving the sharing request, the data center 480 may then transmit the second computed image to the wireless mobile device 376(1). In an embodiment, transmitting the second computed image to the other wireless mobile device 376(1) may include sending a URL at which the other wireless mobile device 376(1) may access the second computed image.

Still further, as shown in FIG. 12, after receiving the second computed image, the other wireless mobile device 376(1) may send to the data center 480 a request to adjust processing of the at least two digital images. For example, the other wireless mobile device 376(1) may display the second computed image in a UI system, such as the UI system 1000 of FIG. 10. A user of the other wireless mobile device 376(1) may manipulate UI controls to adjust the processing of the at least two digital images transmitted to the data center 480 by the wireless mobile device 376(0). For example, user manipulation of a slider control at the other wireless mobile device 376(1) may result in commands being generated and transmitted to data center 480 for processing. In an embodiment, the request to adjust the processing of the at least two digital images sent from the other wireless mobile device 376(1) includes the commands generated based on the user manipulation of the slider control at the other wireless mobile device 376(1). In other embodiments, the request to adjust processing of the at least two digital images includes any instructions from the wireless mobile device 376(1) that the data center 480 may use to again process the at least two digital images and generate a third computed image.

As shown in FIG. 12, upon receiving the request to adjust processing, the data center 480 re-processes the at least two digital images to generate a third computed image. In one embodiment, the data center 480 may re-process the at least two digital images using mix weights received from the wireless mobile device 376(1). In such an embodiment, the mix weights received from the wireless mobile device 376(1) may be provided as input with the at least two digital images to an HDR processing algorithm that executes at the data center 480. After generating the third computed image, the third computed image is then transmitted from the data center 480 to the wireless mobile device 376(1) for display. Still further, after receiving the third computed image, the wireless mobile device 376(1) may send to the data center 480 a request to store the third computed image. In another embodiment, other wireless mobile devices 376 in communication with the data center 480 may request storage of a computed image. For example, in the context of FIG. 12, the wireless mobile device 376(0) may at any time request storage of the first computed image or the second computed image.

In response to receiving a request to store a computed image, the data center 480 may store the computed image for later retrieval. For example, the stored computed image may be stored such that the computed image may be later retrieved without re-applying the processing that was applied to generate the computed image. In one embodiment, the data center 480 may store computed images within a storage system 486 local to the data center 480. In other embodiments, the data center 480 may store computed images within hardware devices not local to the data center 480, such as a data center 481. In such embodiments, the data center 480 may transmit the computed images over the data network 474 for storage.

Still further, in some embodiments, a computed image may be stored with a reference to the at least two digital images utilized to generate the computed image. For example, the computed image may be associated with the at least two digital images utilized to generate the computed image, such as through a URL served by data center 480 or 481. By linking the stored computed image to the at least two digital images, any user or device with access to the computed image may also be given the opportunity to subsequently adjust the processing applied to the at least two digital images, and thereby generate a new computed image.

To this end, users of wireless mobile devices 376 may leverage processing capabilities of a data center 480 accessible via a data network 474 to generate an HDR image utilizing digital images that other wireless mobile devices 376 have captured and subsequently provided access to. For example, digital signals comprising digital images may be transferred over a network for being combined remotely, and the combined digital signals may result in at least a portion of a HDR image. Still further, a user may be able to adjust a blending of two or more digital images to generate a new HDR photograph without relying on their wireless mobile device 376 to perform the processing or computation necessary to generate the new HDR photograph. Subsequently, the user's device may receive at least a portion of a HDR image resulting from a combination of two or more digital signals. Accordingly, the user's wireless mobile device 376 may conserve power by offloading HDR processing to a data center. Further, the user may be able to effectively capture HDR photographs despite not having a wireless mobile device 376 capable of performing high-power processing tasks associated with HDR image generation. Finally, the user may be able to obtain an HDR photograph generated using an algorithm determined to be best for a photographic scene without having to select the HDR algorithm himself or herself and without having installed software that implements such an HDR algorithm on their wireless mobile device 376. For example, the user may rely on the data center 480 to identify and to select a best HDR algorithm for a particular photographic scene.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. An apparatus, comprising:

an array of an image sensor, the array including pixels located in one or more rows; and

circuitry for:

storing an analog signal associated with each pixel;

sending the analog signal associated with each pixel to a column read-out;

receiving the analog signal associated with each pixel from the column read-out;

generating a first amplified analog signal associated with each pixel by amplifying the analog signal utilizing a first gain, the first amplified analog signal including first gain-adjusted analog pixel data representative of a first common analog value from each pixel;

generating a second amplified analog signal associated with each pixel by amplifying the analog signal utilizing

a second gain, the second amplified analog signal including second rain-adjusted analog pixel data representative of a second common analog value from each pixel;

transmitting the first amplified analog signal and the second amplified analog signal;

converting the first amplified analog signal to a first digital signal associated with each pixel;

converting the second amplified signal to a second digital signal associated with each pixel; and

blending the first digital signal and the second digital signal for each pixel, wherein the blending occurs in response to user input and the blending results in at least a portion of a high dynamic range (HDR) image, wherein the blending further produces the HDR image with zero interframe time between the first digital signal and the second digital signal.

2. The apparatus of claim **1**, wherein the apparatus is operable such that the analog signal is amplified utilizing the first gain simultaneously with the amplification of the analog signal utilizing the second gain.

3. The apparatus of claim **1**, wherein the apparatus is operable such that the analog signal is amplified utilizing the first gain in serial with the amplification of the analog signal utilizing the second gain.

4. The apparatus of claim **1**, wherein the first amplified analog signal is converted to the first digital signal concurrent with the conversion of the second amplified analog signal to the second digital signal.

5. The apparatus of claim **1**, wherein the apparatus is operable such that the first digital signal has a first light sensitivity value associated therewith and the second digital signal has a second light sensitivity value associated therewith.

6. The apparatus of claim **1**, wherein the apparatus is operable such that sliding indicia is displayed and the first digital signal and the second digital signal are blended, in response to the sliding indicia being manipulated by a user.

7. The apparatus of claim **1**, wherein the apparatus is operable such that at least one of the first digital signal or the second digital signal associated with the HDR image is further combined with at least a portion of another image.

8. The apparatus of claim **7**, wherein the apparatus is operable such that the another image is a high dynamic range (HDR) image.

9. The apparatus of claim **1**, wherein a first digital value specifies the first gain, and a second digital value specifies the second gain.

10. The apparatus of claim **9**, wherein at least one of the first digital value and the second digital value is selected based on a mapping from the at least one of the first digital value and the second digital value to an ISO value, and the ISO value is selected by at least one of software executing on the apparatus and a user.

11. The apparatus of claim **1**, wherein the apparatus is operable for transferring at least one of the first digital signal or the second digital signal over a network.

12. The apparatus of claim **1**, wherein the apparatus is operable for transferring at least one of the first digital signal or the second digital signal over a network for being combined remotely with a third digital signal.

13. The apparatus of claim **1**, wherein the apparatus is operable for transferring the HDR image over a network for being combined remotely with a third digital signal.

14. A computer program product embodied on a non-transitory computer readable medium, comprising:

code for storing an analog signal associated with each pixel of an array of an image sensor;

code for sending the analog signal associated with each pixel to a column read-out;

code for allowing receipt of the analog signal associated with each pixel from the column read-out;

code for generating a first amplified analog signal associated with each pixel by amplifying the analog signal utilizing a first gain, the first amplified analog signal including first gain-adjusted analog pixel data representative of a first common analog value from each pixel;

code for generating a second amplified analog signal associated with each pixel by amplifying the analog signal utilizing a second gain, the second amplified analog signal including second gain-adjusted analog pixel data representative of a second common analog value from each pixel;

code for transmitting the first amplified analog signal and the second amplified analog signal;

code for converting the first amplified analog signal to a first digital signal associated with each pixel;

code for converting the second amplified signal to a second digital signal associated with each pixel; and

code for blending the first digital signal and the second digital signal for each pixel, wherein the blending occurs in response to user input and the blending results in at least a portion of a high dynamic range (HDR) image, wherein the blending further produces the HDR image with zero interframe time between the first digital signal and the second digital signal.

15. A method, comprising:

storing an analog signal associated with each pixel of an array of an image sensor;

sending the analog signal associated with each pixel to a column read-out;

receiving the analog signal associated with each pixel from the column read-out;

amplifying the analog signal utilizing a first gain resulting in a first amplified analog signal associated with each pixel, the first amplified analog signal including first gain-adjusted analog pixel data representative of a first common analog value from each pixel;

amplifying the analog signal utilizing a second gain resulting in a second amplified analog signal associated with each pixel, the second amplified analog signal including second gain-adjusted analog pixel data representative of a second common analog value from each pixel;

transmitting the first amplified analog signal and the second amplified analog signal;

converting the first amplified analog signal to a first digital signal associated with each pixel;

converting the second amplified signal to a second digital signal associated with each pixel; and

blending the first digital signal and the second digital signal for each pixel, wherein the blending occurs in response to user input and the blending results in at least a portion of a high dynamic range (HDR) image, wherein the blending further produces the HDR image with zero interframe time between the first digital signal and the second digital signal.

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